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THE

VOYAGE OF H.M.S. CHALLENGER.

ZOOLOGY—VOL. XI.

REPORT

ON THE

SCIENTIFIC RESULTS

OF THE

VOYAGE OF H.M.S. CHALLENGER

DURING THE YEARS 1873-76

UNDER THE COMMAND OF

CAPTAIN GEORGE S. NARES, R.N., F.R.S.

AND THE LATE

CAPTAIN FRANK TOURLE THOMSON, R.N.

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PREPARED UNDER THE SUPERINTENDENCE OF

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AND NOW OF

JOHN MURRAY

ONE OF THE NATURALISTS OF THE EXPEDITION

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CONTENTS.

I.—Report on the Keratosa collected by H.M.S. Challenger, duri 1873–1876.

By N. Polèjaeff, M.A., of the University of Odessa.

(*Received* 16*th April* 1884.)

II.—Report on the Crinoidea collected during the Voyage of H.M.S. during the years 1873–1876.—The Stalked Crinoids.

By P. Herbert Carpenter, D.Sc., Assistant Master at Eton Coll

(*First instalment of Manuscript received* 18*th March* 1884; *the last* 13*th De*

III.—Report on the Isopoda collected by H.M.S. Challenger, duri 1873–1876.—The Genus *Serolis*.

By Frank Evers Beddard, M.A. (Oxon), F.R.S.E., F.R.M.S., F.Z.S., Prosector to the Zoological Society of Londor

(*Received* 6*th September* 1884.)

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EDITORIAL NOTES.

THIS volume contains Parts XXXI., XXXII., and XXXIII. of the Zoological Series of Reports on the Scientific Results of the Expedition.

Part XXXI.—The Report on the CALCAREA, by Dr. N. Poléjaeff, was published at the end of last year as Part XXIV. of the Zoological Series of Reports, and the present Report on the KERATOSA is by the same author, and will be welcomed by all Spongiologists.

The Manuscript was received on 16th April 1884.

Part XXXII.—THE STALKED CRINOIDS, both on account of their rarity and their palæontological relations, are perhaps the most interesting and remarkable of deep-sea animals, and have been in a special manner associated with the Challenger Expedition.

The joint work of the late Sir C. Wyville Thomson and Dr. W. B. Carpenter, C.B., first on *Comatula* and afterwards on *Pentacrinus*, together with the discovery by Professor G. O. Sars of *Rhizocrinus* off the Lofoten Islands in 1864, led directly to the expeditions of the "Lightning" and "Porcupine" in 1868 and the following years, and was thus indirectly concerned in the despatch of the Challenger Expedition in 1872. Sir Wyville Thomson himself proposed to draw up the Report on this group of animals, to which he had devoted much attention during the cruise. The circumstances which led to Dr. P. Herbert Carpenter undertaking the preparation of the Report after Sir Wyville Thomson's death in 1882 are referred to in detail in the Preface to the Report.

The Manuscript was received by me in batches between 18th March 1884 and 13th December 1884.

Part XXXIII.—This Monograph of the genus *Serolis* is the first instalment of a Report on the ISOPODA collected during the Expedition, by Frank Evers Beddard, Esq., M.A. (Oxon), Prosector to the Zoological Society of London.

Mr. Beddard was for nearly two years associated with me in the work of this office, and I embrace this opportunity of acknowledging the very valuable assistance he rendered in connection with the translation and editing of many of the Reports.

The Manuscript was received on 6th September 1884.

JOHN MURRAY.

CHALLENGER OFFICE, 32 QUEEN STREET,
EDINBURGH, *30th December* 1884.

THE

VOYAGE OF H.M.S. CHALLENGER.

ZOOLOGY.

REPORT on the KERATOSA collected by H.M.S. Challenger during the years 1873-76. By N. POLÉJAEFF, M.A. of the University of Odessa.

INTRODUCTION.

THE Keratose Sponges do not belong to the deep-sea fauna; it is therefore not surprising that the number of forms brought home by the Challenger Expedition does not exceed the comparatively small number of thirty-seven (twenty-one new, three undeterminable). But if not numerous, the collection is still very interesting, embracing as it does almost all the genera of the horny sponges hitherto distinguished, and most of the specimens being in a very good state of preservation.

Entering upon their classification and description, I feel myself in a position rather different from that which I occupied some months ago when writing about the Challenger Calcarea. For in this latter case I had to deal with but one elaborate system (that of Haeckel), and my task consisted simply in the reconciliation of Haeckel's systematic arrangement with the modern state of spongiological knowledge. In the group of Keratose Sponges the classifier meets with many detailed systems, constructed in many instances upon radically different principles. My first task is consequently to show which of the existing systems is to be most recommended, and with what modifications. There are two ways of doing this. One way might be called "historical," and would consist of a critical discussion in chronological order of all the systems of the horny sponges we possess; the second might be called "morphological," and would consist of a critical discussion of the comparative systematic value of their different organs. I purpose choosing this latter mode, for the following reasons. Firstly, because it ensures the avoidance of superfluous repetitions, the existing arrangements of the Keratosa being con-

flicting in some points and harmonious in others. Secondly, because it promises more logically fitting opportunities, whilst discussing the discoveries of other spongiologists, of communicating whatever observations of general interest I have made whilst examining the Challenger material, so that the descriptive part of this memoir may be for the most part exclusively devoted to systematic purposes. The following pages accordingly consist of a discussion of the organisation of the Keratosa and of the principles of their classification.

I.—ORGANISATION AND CLASSIFICATION OF THE KERATOSA.

One might perhaps feel inclined to say that this title promises but very little; that a classifier has to search for systematic characters not only into the organisation of the animals in question, viz., into their Anatomy and Histology, but also into other regions of Biology, and, in the first instance, into Embryology and Palæontology. Unluckily this is impossible so far as the horny sponges are concerned. Some fossils have been described which may possibly be referred to the Keratosa, but this cannot be regarded as scientifically proved, nor is the number of such forms sufficient to permit any further conclusions.[1] The possibility of a *future* application of Palæontology to phylogenetic purposes respecting the Keratose Sponges is not entirely excluded, though there are reasons to believe that this group is a very recent one, but up to the present time the application above mentioned is impossible. Again, with respect to embryological data even such a modest hope cannot be assumed. Of course our knowledge is still very fragmentary, but what we know only confirms the opinion that the ontogeny of the horny sponges is very monotonous, and that therefore its further profound study would probably be of consequence only for the solution of certain *embryological* problems (in the strict sense of the word), but not of much service in augmenting the number of systematically important characters. The classifier is thus thrown on the resources of Anatomy and Histology alone; chiefly on those of Anatomy, since it is only in exceptional cases, as in *Ianthella* or *Cacospongia vesiculifera*,[2] that histological characters can be applied to systematic purposes. But, nevertheless, this would be of no further consequence were the anatomical characters of, so to speak, unconditional value. Yet even this is not the case, and this is just what renders the classification of the Keratosa so very difficult, and makes the danger of "describing individuals instead of genera and species" (O. Schmidt) greater in this group than elsewhere. For Comparative Anatomy can only state this or that difference in organisation, but is very often quite powerless, at least in the Keratosa, to decide the question whether this or that anatomical peculiarity is constant or merely accidental. It is therefore obvious that the systems of the Keratosa we are now so diligently elaborating will prove, with the progress of the Comparative Physiology, to

[1] Zittel, Zur Stammesgeschichte der Spongien, München, 1878, p. 9.

[2] Page 58 of this Report.

be in many points quite artificial; but we must console ourselves with the impossibility of altering the matter, and although with respect to this group we have to deal with anatomical characters almost exclusively, we must ground upon them our systematic arrangements, proceeding, however, with all possible prudence, and bearing in mind the necessity of a critical attitude towards our own conclusions.

These general remarks will now be followed by more special observations as to the systematic value of various characters of the sponges in question. I begin with the properties of the skeleton. Its high systematic significance has always been recognised; what is more, it has been exaggerated. The systems of Duchassaing de Fonbressin and Michelotti,[1] of Gray,[2] Hyatt,[3] Carter,[4] are founded simply on its properties. In the diagnoses of the last-named naturalist, indeed, the "sarcode" is also very often spoken of; but these particulars might in almost all cases be omitted; and it is precisely owing to the circumstance that the former spongiologists were inclined to pay to the properties of the skeleton an exclusive attention, that its modifications for a long time past have been submitted to a careful study, and considerable differences in its structure discovered. It has been stated that while in some of the Keratose Sponges the horny fibres show no differentiation in their central and peripheral parts, the fibres of the skeleton of many others admit of a distinction into a central pith-substance ("Marksubstanz" of German authors) and of a horny laminar envelope; and while the *homogeneous* fibres are almost always more or less cored with foreign bodies, so that the horny substance shows in many instances a tendency to disappear entirely, the *heterogeneous* skeletal fibres, on the contrary, are in most cases quite free from any foreign enclosures. Finally, it has been stated that in certain sponges (*Ianthella*) the horny envelope of their skeletal fibres is charged with true cells (Flemming,[5] Carter[6]). To the first of these characters the greatest systematic significance has been repeatedly ascribed, and the two spongiologists to whom we owe the most elaborate systems of Keratosa (Carter and Hyatt) have made use of it in order to subdivide the group into two main divisions (Ceratina and Psammonemata, Carter; Aplysinæ and Spongiæ, Hyatt), which proceeding deserves a more detailed critical study, since we have recently learned from the spongiological writings of F. E. Schulze that the above-mentioned differences in the properties of the skeleton present a certain antagonism with regard to the internal structure of the soft parts, that both in Ceratina or Aplysinæ and Psammonemata or Spongiæ two types, or at least modifications, of the canal system, are to be seen. Schulze ascertained, in fact, that while an *Aplysina*, and on the other hand a *Euspongia* or *Cacospongia*, are characterised, in the organisation of their canal system, by comparatively small, round, or pear-shaped

[1] Spongiaires de la mer Caraibe, Harlem 1864.
[2] *Proc. Zool. Soc. Lond.*, 1867, pp. 503, 508.
[3] Revision of the North American Poriferæ, *Boston Soc. Nat. Hist.*, 1875 and 1877.
[4] *Ann. and Mag. Nat. Hist.*, ser. 4, vol. xvi. pp. 132, 134–140, 1875.
[5] *Würzburger Verhandl.*, N. F., Bd. ii.
[6] *Ann. and Mag. Nat. Hist.*, ser. 5, vol. viii. p. 112, 1881.

flagellated chambers, each possessing its own narrow inhalent and exhalent canaliculi, and while the ground-mass surrounding these flagellated chambers is always opaque owing to the presence of small granules, the forms like *Spongelia* and *Aplysilla* possess no special cameral canaliculi, their large pouch-shaped flagellated chambers receiving the water from the subdermal cavities directly by means of the pores in their walls, and expelling it also immediately, without the help of any intermediate narrow canals, into large exhalent cavities, the diameter of these latter being usually far larger than that of the exhalent opening of the corresponding flagellated chambers; and that in these latter instances the parenchyma in the zone of the flagellated chambers is devoid of any granules, being lucid and transparent.

It remains to be decided what position the modern systematist should take with respect to the antagonism in question. F. E. Schulze himself gives in his papers no answer to it. He assigns[1] to *Aplysilla* the place of a new genus in his family Aplysinidæ, while he is inclined to regard the genus *Spongelia*, an analogue of *Aplysilla* in the Keratosa with homogeneous skeletal fibres, as the representative of an independent family.[2] Again, his distinguished pupil Dr. Vosmaer, stands also perfectly neutral, dividing, in his interesting paper on *Velinea gracilis*,[3] all the Keratosa directly into families, according to the properties both of the soft parts and of the skeleton. But though neutral as far as his actions are concerned, Dr. Vosmaer expresses very clearly his opinion on the matter. He does not ascribe any special importance to the difference between the fibres, whether homogeneous or heterogeneous. On the contrary, another pupil of Prof. Schulze, Dr. v. Lendenfeld, seems inclined to accept the opinions of Hyatt and Carter. At least, in his memoir on the Aplysinidæ of the South Sea, he characterises[4] the family of Aplysinidæ by their heterogeneous skeletal fibres, splitting it into two subfamilies, that of Aplysininæ and Aplysillinæ, according to the type of the canal system. And, indeed, such a proceeding appears at first sight very logical and natural. Of course, on the whole, the canal system is of greater significance for the sponge organism than the skeleton. No sponge can be imagined without canal system, be it represented as in Asconidæ by the undifferentiated central cavity without any trace of separate flagellated chambers, or, as in *Aplysina* or *Corticium*, by a very complicated system of subdermal cavities, inhalent cameral canaliculi, flagellated chambers, exhalent canaliculi, &c., while there are sponges, like *Halisarca*, *Oscarella*, or *Chondrosia* without any supporting apparatus. It should not, however, be overlooked that whatever importance may be ascribed to the canal system, this importance is of a pronounced physiological character. On the contrary, so far as the properties of the skeleton are concerned,—all this holds true within the group Keratosa, and the last-mentioned point with regard to its internal

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxx. p. 404.
[2] *Zeitschr. f. wiss. Zool.*, Bd. xxxii. p. 117.
[3] *Mittheilungen a. d. zool. Station zu Neapel*, 1883, p. 444.
[4] *Zeitschr. f. wiss. Zool.*, Bd. xxxviii. p. 309.

structure,—they appear to be of a more trustworthy morphological character. The function of the skeleton is to support the soft parts. The heterogeneous and homogeneous skeletal fibres are equally fit for this function; and when once a sponge has adopted the heterogeneous fibres, it would but conserve them. One might logically compare the heterogeneous and homogeneous skeletal fibres with calcareous and siliceous skeletal spicules, these latter propping the sponge-sarcode equally well in both cases; and since it is necessary to separate systematically the Calcarea and Silicea, it must be equally necessary to separate the Ceratina and the Psammonemata.

To sum up, the procedure of the above-mentioned systematists may be regarded as very logical. Yet each question admits of numerous answers equally logical and undeniable; and it is not to be forgotten that what we think to-day to be thoroughly logical, we may perhaps regard to-morrow as quite impossible, that the really logical is that which alone corresponds with the reality. The ascribing of such systematic importance to the properties of the skeleton in question cannot be reconciled with the reality, and in no case can these properties serve as the basis for the primary subdivision of the group Keratosa. Such a subdivision would express that the Keratosa with homogeneous skeletal fibres form one phylogenetic branch of the group, the Keratosa with heterogeneous fibres another, phylogenetically equivalent to the first, the intermediate connecting links having died out. This, however, is not the case, the differences in the structure of horny fibres, as already pointed out by Vosmaer, being but of a quantitative nature. There are amongst the Keratosa, forms, the horny envelope of whose heterogeneous skeletal fibres is very thin (*Aplysina*, *Aplysilla*, *Darwinella*), so that the pith-substance forms the main part of the fibre; there are again other forms (*Verongia*, *Luffaria*), the horny walls of whose fibres are far thicker, and, at least in some representatives of the genus *Luffaria*, there are to be found amongst fine fibres, fibres quite similar to those of *Euspongia*, or *Spongelia*, viz., fibres apparently entirely devoid of any central differentiation (Pl. IX. fig. 6). I say apparently, for, thanks to F. E. Schulze, we know that each normal horny fibre does possess what he calls an "Achsenstrang." He has been able to discern it in the fibres of *Euspongia*[1] and *Spongelia*,[2] and that certain homogeneous fibres show no differentiation, even under high microscopic power, seems to be due to the fact that, hand in hand with a more voluminous development of the pith-substance, there is a variation in its chemical and optical properties. In the fibre of an *Aplysina* or *Aplysilla* the core and the surrounding horny laminæ can be readily distinguished under very low magnifying power, and the designation "hollow-fibred," which has been adopted by many spongiologists with respect to forms like *Aplysilla* or *Verongia*, owes its existence to the fact that even when simply dried out, the skeletal fibres of the above forms show no more trace of the pith-substance.

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxxii. p. 633.

[2] *Ibid.*, pl. vi. figs. 6 and 7.

On the other hand, in *Luffaria* the horny laminæ and the central differentiation of its fibres resemble each other optically in a far greater degree; higher powers of the microscope are necessary in order to show this internal differentiation; when dried, the fibres still possess their core, and only after treatment with caustic alkali or ammonia do the fibres become hollow. Certain differences are also to be found in the structure of the pith-substance. While in *Aplysina* or *Verongia* the core is represented by a fine and irregularly twined network,[1] in *Luffaria* the structure of the core of its fibres appears similar to that of its horny envelope, being however represented not by continuous laminæ, but by minute horny splints, still disposed parallel to one another, as well as with regard to the surrounding laminæ, just as Schulze has figured[2] the central canal of the fibres of *Spongelia pallescens*. But though the core of the skeletal fibres of *Luffaria* appears to be structurally quite equivalent to that of *Euspongia*, and differs considerably from that of typical Aplysinidæ, it would still be premature to assume that *Luffaria* is but a specifically modified Spongid, and not a link connecting the Aplysinidæ with the Spongidæ, in consequence of the identical manner in which both kinds of fibres, the heterogeneous as well as homogeneous, develop.

It has indeed been stated—I allude to Dr. v. Lendenfeld's[3] observations—that the development of the heterogeneous fibres only slightly resembles that of the homogeneous ones; that while, according to Schulze,[4] the skeletal fibres of a *Cacospongia* or *Euspongia* grow by reason of the activity of *spongoblasts* exclusively, the growth of a heterogeneous fibre is dependent on the function both of spongoblasts and *spongoklasts*. Like F. E. Schulze, Dr. v. Lendenfeld distinguishes two kinds of spongoblasts—those of elongated, and those of polygonally massive, form; the first are to be found along the developing fibre, the second on its summit. He thinks, however, that the function of the last-named is not to secrete the pith-substance of the central canal, but to sink down into the interior of the developing fibre, in order to transform into pith-substance the original horny mass, secreted by the elongated spongoblasts (Ich nehme an, dass die Zellen in den Kuppeln, gleich den Osteoklasten der Wirbelthiere, die harte Rinde der Skelettheile auflösen und in Marksubstanz verwandeln). This statement Dr. v. Lendenfeld accompanies by an illustration, and recalls on this occasion the statements of Flemming as to the structure of the skeletal fibres of *Ianthella*, which he (Dr. Lendenfeld) supposes to be very nearly allied to his *Dendrilla*, and in whose fibres the presence of true cells has been proved. Of course there can be no doubt that the skeletal fibres of *Ianthella* are charged with true cells. The statements of Flemming have been corroborated by Carter, and, for my own part, I can only confirm their observations Yet these cells have been found not in the pith-substance, but between the surrounding

[1] Comp. F. E. Schulze's statements on this point in *Zeitschr. f. wiss. Zool.*, Bd. xxx. p. 401, and my drawing, Pl. X. fig. 3.
[2] *Zeitschr. f. wiss. Zool.*, vol. xxxii., pl. vi. fig. 6; comp. my drawing, Pl. IX. fig. 6.
[3] *Zeitschr. f. wiss. Zool.*, vol. xxxviii. p. 291.
[4] *Ibid.*, vol. xxxii. p 635.

horny laminæ, and Flemming,[1] like Carter,[2] emphatically denies their occurrence in the core of the fibres. My own endeavours to discern them there have been equally unsuccessful, and this not only with regard to *Ianthella*, but also with regard to *Verongia*, *Aplysina*, *Darwinella*, and *Aplysilla*, in which connection I should lay stress on the fact that the specimens of *Aplysilla sulphurea*, kindly placed at my disposal by Prof. F. E. Schulze, have been examined both in the living state as well as preserved by the methods recommended by Dr. v. Lendenfeld. In no single case have I been able to discern in the central canal of the horny fibres anything that might be regarded as spongoklasts.

Again, Dr. Vosmaer states the same with respect to his *Velinea gracilis*.[3] And far from supposing that Dr. v. Lendenfeld has described what he did not see, I feel convinced that he has misinterpreted what he did see. It may be said that what does not occur in *Ianthella* or *Aplysilla* may be characteristic of *Dendrilla*. Such a possibility indeed is not excluded, but it is extremely improbable. For, firstly, *Dendrilla* seems to be so closely allied to *Aplysilla* that both these genera will probably in time be united into one; and secondly, because with an instrument like the microscope one sees very often precisely what one desires to see, and that Dr. v. Lendenfeld has been desirous to find out his spongoklasts is beyond any doubt, the spongoklasts having been for him a logical necessity. He refers in his above-mentioned memoir to the statements of F. E. Schulze as to the fact that, though on the whole the old larger skeletal fibres of *Aplysina aërophoba* must be called thick-walled, the young ones of small diameter on the contrary thin-walled, still the diameter of the central pith-substance in larger fibres is comparatively greater than that of the small ones. He tells us further that the same can also be said with respect to the Aplysillidæ which he had for examination, and he deduces from this the conclusion that hand in hand with the growth of the fibre its pith-substance increases also.[4] If all this be so, indeed, without the theory of spongoklasts, the phenomenon would be quite inconceivable. I must, however, deny the reliability of the statements in question. The fibres of the representatives of the genera *Ianthella*,[5] *Verongia*, and *Luffaria* have been submitted by me to the most careful examination, and I must state that in all the above specimens I found very often fibres of the same size but with different diameters of the central canal; and since I find also that this is the case not only as regards the fully developed fibres but also those in embryonic condition, I believe that the phenomenon we are speaking of is easily explained without any reference to spongoklasts, if we assume that the pith-substance is a product of the *polygonal* spongoblasts, and the laminar horny substance the product of those of elongated shape, and that the differences in diameter of the central canals are dependent upon their having been deposited broad or narrow. The second

[1] *Loc. cit.*, p. 4.
[2] *Loc. cit.*, p. 115.
[3] *Loc. cit.*, p. 441.
[4] *Loc. cit.*, p. 290–293.
[5] I should call attention to the fibres constituting the skeleton of the stem of this sponge; some of them are far thicker than the primary fibres of its leaf-like part, but, nevertheless, with the diameter of the central canal not only considerably smaller than that of the primary fibres just mentioned, but occasionally not larger than that of a *Spongelia*.

conclusion, as stated before, is founded on actual facts; as to the first, I have no decisive proofs for it, but I believe it will yet be adopted, at least provisionally, as a hypothesis of comparatively great probability. That it is so, when compared with that of Dr. v. Lendenfeld, is evident, since it does not, as does his theory, contradict the actual facts; that, again, the intussusception theory of Prof. Schulze[1] is not plausible has been indicated by Dr. v. Lendenfeld[2] himself.

The foregoing remarks have had two distinct aims: first, to give a plausible explanation of the phenomenon of the formation of the horny fibres; and second, to show that this phenomenon is the same with regard both to the homogeneous and heterogeneous fibres. Whether I have succeeded in my first task will be shown by later investigations; at any rate we must assume that the elements forming the homogeneous horny skeletal fibres are just the same as those secreting the heterogeneous fibres; and since in both cases no special functional transformations of any of these elements take place, we must come to the conclusion that, in thorough harmony with the fact that homogeneous and heterogeneous horny fibres differ from one another only quantitatively, the development of both kinds of fibres admits also of only relative distinction; and that, accordingly, the subdivision of the Keratosa into two groups, the one characterised by homogeneous, the other by heterogeneous, skeletal fibres, would be thoroughly artificial. Whether such a subdivision may be made according to the structure of the canal system will be discussed later on. I proceed for the present to treat of the modifications of the skeleton, and now pass on to those influenced by the tendency of most of the Keratosa to take up foreign bodies into their skeletal fibres.

As is well known, this tendency is characteristic only of Keratosa with homogeneous skeletal fibres. Beginning with forms like most *Coscinodermata* and *Hippospongiæ*, whose fibres contain foreign bodies only exceptionally, here and there a sand-grain or fragment of a spicule, going on to forms like many representatives of the genera *Euspongia* and *Cacospongia*, whose primary fibres are full of foreign enclosures, but the secondary ones in most cases quite free from them, and, further, passing by forms like *Psammoclema vosmaeri* or *Spongelia avara*, both kinds of fibres of which are overcharged with foreign enclosures, we come to the genus *Psammopemma*, characterised by an entire absence of any fibres, the supporting skeleton consisting of sand-grains, portions of Foraminiferal shells, fragments of spicules, &c., all lying separately, the secretion of the horny substance being reduced to the formation of a thin horny envelope around each foreign body.

To this tendency, again, a high systematic importance has been ascribed. Gray[3] and Marshall[4] characterise their family of Dysideidæ mainly by the richness of their fibres in foreign enclosures. The systematic application of this character plays also a great

[1] *Zeitschr. f. wiss. Zool.*, vol. xxx. p. 403.
[2] *Loc. cit.*, p. 291–292.
[3] *Proc. Zool. Soc. Lond.*, 1867, p. 503.
[4] *Zeitschr. f. wiss. Zool.*, vol. xxxv. p. 92.

part in the system of Mr. Hyatt.[1] Again, Mr. Carter makes an exclusive use of it as to the special subdivisions of his order of Psammonemata, following the principle of "beginning with horny fibre sparingly cored with foreign bodies, in order to go to that in which the core is more general, and finally to end with that in which the horny element is scarcely visible, and the core of foreign bodies only held together by a minimum of sarcode, like the spicules in the Holorhaphidota."[2] That, as a matter of fact, *all* the naturalists in question have been wrong in this proceeding is clear to every one who is at all acquainted with the recent progress of spongiology; but as to Mr. Hyatt, I must still add that logically he has had the best grounds for the division of the genus *Dysidea* (*Spongelia*) into two independent families. His dermal-membrane theory of the formation of skeletal fibres is false; the dermal membrane, as we know now, stands in no connection with this formation. Furthermore, it is improbable even theoretically, and indeed more difficult to understand than the phenomenon itself, but having once adopted the idea that in different sponges the secondary fibres are of quite different origin (those of his *Spongelia* owing their formation to his "mesoderm," those of his *Dysidea* to his "ectoderm"), he was certainly right in ascribing to this difference the significance of a family character. For this character would be an *absolute* character, while Carter and Marshall have been sure of the contrary. Of course, the proceeding of Mr. Carter is still comprehensible, since his system was devised before the important investigations of F. E. Schulze were published, but the proceeding of Dr. Marshall is to me quite inconceivable. He makes use of a quantitative distinction in order to characterise a family.[3] I am very well aware that the systematic definitions we give to the species, genera, and accordingly to the families, particularly when young groups of animals are concerned, must be according to circumstances more or less conditional. But this is the privilege of natural arrangements. Is that of Dr. Marshall's Dysideidæ a natural one? Surely not. Among his Dysideidæ we find sponges with quite different internal organisation. We find[4] there *Oligoceras collectrix*, F. E. Schulze, a sponge whose canal system follows the type of that of Spongidæ; we find[5] there some representatives of the genus *Dysidea*, whose canal system presents, according to Marshall, quite different characters—those of a vesicular type; we find[6] there also sponges with a canal system arranged according to the so-called dendroid type, which has no more real existence than the vesicular type; finally, we find[7] there sponges whose canal system could not have been made out, the specimens having been very badly preserved. Dr. Marshall calls F. E. Schulze the most eminent spongiologist of the present time; he calls his spongiological papers brilliant; but the chief merit of F. E. Schulze consists precisely in having made

[1] Revision, &c., part ii. p. 482.

[2] *Ann. and Mag. Nat. Hist.*, ser 4, vol. xvi. p. 135, 1875.

[3] "Die Dysideiden sind Hornschwämme bei denen die auch allen übrigen Hornschwämmen in höherem oder geringerem Masse innewohnende Fähigkeit das eigene Skelett durch aufgenommene Fremdkörper zu verstärken, den höchsten Grad erreicht hat."—*Loc. cit.*, p. 92.

[4] *Loc. cit.*, p. 92.

[5] *Loc. cit.*, p. 99.

[6] *Loc. cit.*, p. 105.

[7] *Loc. cit.*, p. 98.

out the internal organisation of the Porifera and applied it to systematic purposes. Prof. Schulze[1] characterises his family of Spongelidæ primarily by the structure of the soft parts; in Dr. Marshall's diagnosis of Dysideidæ not a single word is devoted to this character. Does he regard it as devoid of any systematic importance? This seems to be the case, but the grounds for this opinion are not to be found in Dr. Marshall's paper, and without this the paper in question is of very doubtful profit for systematic knowledge, and this is the case with *every paper on the Keratosa based on specimens insufficiently preserved for anatomical examination.* Such papers, if from the pen of authors of talent, may still contain something of general interest, and this is in a high degree the case with regard to Dr. Marshall's memoir on Dysideidæ and Phoriospongiæ, but just on that account it is the more to be regretted that from a systematic point of view this memoir only renders the systematic chaos relating to the group Keratosa still more impenetrable.

In the Bemerkungen über die neue Gray'sche Hornschwammgattung Ianthella[2] by Dr. Flemming, spongiological literature has been enriched with a new and very valuable contribution to our knowledge of the properties of the horny skeleton. Dr. Flemming has stated—and, as I before remarked, I can but confirm his statements—that the fibres of *Ianthella flabelliformis* and *Ianthella basta* contain true cells between the laminæ of their walls. The specimens of both (?) the species obtained and examined by Dr. Flemming were dried, and thus he has not been able to decide the question as to whether *Ianthella* is really to be referred to *Porifera.* He believes, however, that, if so, a very isolated place in the group is to be assigned to this sponge ("Es scheint mir zunächst nicht viel übrig zu bleiben, als sie bei den Spongien, aber auf einem sehr isolirten Platze einstweilen stehen zu lassen").[3] Dr. Flemming's suggestion is to be regarded as quite natural, if we remember that his paper on *Ianthella* appeared in the year 1871, *i.e.*, five years before the important discovery of spongoblasts by F. E. Schulze; but at present one may perhaps form another opinion as to the systematic importance of the peculiarity in question. The gist of the matter consists in the fact that each horny fibre is the product of cellular elements; and whether the spongoblasts, after having accomplished one part of the work, recede before the developing fibre in order to partake in its further growth, or remain in their former places in order to be buried in the horny substance secreted by younger spongoblasts, seems to me to be of secondary significance. Dr. Flemming demands for *Ianthella* a quite isolated place amongst the Keratosa; again, Gray, Carter, and Hyatt, on the ground of characters of undoubtedly less value, of characters to which in other instances we should apply only a generic if not a specific significance, are inclined to regard it as the representative of an independent family. For my own part, I must confess frankly that the systematic importance of the peculiarity we are speaking of is rather ambiguous. For though, as before

[1] *Zeitschr. f. wiss. Zool.*, vol. xxxii. p. 153.

[2] *Würzburg Verhandl.*, N. F., Bd. ii.

[3] *Loc. cit.*, p. 7; comp. also p. 6.

stated, from a theoretical point of view it appears to be but of a subordinate character, the possibility is not excluded that the property in question might have been assumed very early (in a palæontological sense), and thus if we should in time find Ianthellidæ, *i.e.*, horny sponges whose skeletal fibres are charged with true cells, of thoroughly different internal organisation, we should be obliged to elevate the character in question to the rank of that of a subfamily or even family. But hitherto this has not been the case; all the Ianthellidæ known up to this time are only representatives of the same genus, and in order to avoid a superfluous overburdening of spongiological nomenclature, sufficiently overburdened already, I should propose to regard temporarily the genus *Ianthella* as merely a genus of the family Darwinellidæ (Aplysillidæ), the more so as to a similar variation (in the reverse direction, however,) in the Vertebrata[1] no systematic consequence has been ascribed.

This would be the place to discuss the systematic value of the organisms known by the name of "Fibrillen" or "filaments," which for a long time have been considered a constituent part of the horny skeleton. The inducement to this has been given by the statements of Oscar Schmidt, who thought[2] he had seen filaments in immediate connection with true horny fibres. On the ground of this false supposition he adopted the genus *Hircinia*, Nardo, and characterising it primarily by the presence of filaments, subdivided it into two subgenera; Gray[3] in the year 1867, relying on Oscar Schmidt's statements, established a new family "Hircinidæ," characterised by the possession of a, so to speak, double skeleton. There has been however, on the part of other spongiologists, some doubt as to the reliability of Schmidt's statements. Kölliker[4] proclaimed the filaments to be parasites, and this opinion has been warmly defended also by Mr. Carter,[5] apart from the point that, according to Kölliker, the filaments are fungi, according to Carter, algæ. In the meantime, Prof. Schmidt[6] altered his opinion; further and more careful examination led him to the conclusion that the filaments were in no connection with the true skeleton, and this suggestion has been confirmed also by Schulze in his paper on "die Gattung *Hircinia*, Nardo und *Oligoceras*, g. n." Agreeing so far as the real facts are concerned, both the investigators just named differ, however, with regard to further conclusions. In his report on the Spongien der Küste von Algier Prof. Schmidt believes[7] that if it were once proved that the filaments are nothing but parasites, the genus *Hircinia* ought to be dissolved as an independent genus, and incorporated in the genus *Cacospongia*. Prof. Schulze comes to quite a different conclusion; while inclined, as he has been, to regard the filaments as independent organisms, he ascribes[8] to their presence in certain Keratosa a generic and even family character, which

[1] I allude to the osteoblastless skin-bones of Cœciliæ (Leydig) as well as to the equally osteoblastless bones of Teleostei supporting their fins (Kölliker).

[2] Spong. d. Adriat. Meeres, pl. iii. fig. 10.

[3] *Proc. Zool. Soc. Lond.*, 1867, p. 503.

[4] Icones histologicæ, Abth. i. p. 49.

[5] *Ann. and Mag. Nat. Hist.*, ser. 4, vol. viii. p. 330, 1871.

[6] *Zeitschr. f. wiss. Zool.*, Bd. xxxi. p. 661.

[7] *Loc. cit.*, p. 36.

[8] *Zeitschr. f. wiss. Zool.*, Bd. xxxiii. p. 34.

opinion, in spite of objections made by Dr. Marshall,[1] has also been adopted by Dr. Vosmaer.[2] Prof. F. E. Schulze is indeed the most eminent spongiologist of the present time; Dr. Vosmaer is his pupil, and since I have entirely different ideas on the matter, I must submit it to a most careful examination. There are three questions to be answered, namely, first, whether the filaments form a constituent part of the organism of certain sponges or are independent organisms? second, if they are independent organisms are they to be regarded as parasites? and third, if so, is their presence to be used as a character of systematic consequence?

Do the filaments stand in an intimate connection with the sponge organism, or are they independent beings? We have seen that this question has been answered in the negative by numerous investigators. This negative answer has, however, had either no foundation in fact, or only an ambiguous one, till F. E. Schulze's paper on *Hircinia* appeared. What we read in the Icones histologicæ of Kölliker (p. 49) is to be regarded merely as a simple supposition; in the papers of Carter and Hyatt we have indeed to deal with a conviction, but this conviction is far from being contagious. Hyatt states[3] nothing more than that the examination of filaments by Dr. Farlow led to no definite results as to their nature. Carter wishes to prove their parasitic nature by the fact that he did find filaments in many non-Keratosa, and again missed them in notorious Hircinidæ such as *Hircinia campana*. It may be said, however, that, as to the latter argument, the sponges in question have accordingly not been Hircinidæ, and as to the former one, that it is also of no decisive nature, the reliability of the observations upon the point being still questionable. This has been pointed out by F. E. Schulze in his above-mentioned paper (p. 33), and there has been no answer on the part of Mr. Carter. The discovery of O. Schmidt that the filaments, which by their shape vividly recall skipping-ropes, are quite free at both extremities, proved that they had nothing to do with the skeleton, but did not prove their independence of the sponge organism in general. This latter has been made obvious by Schulze, who made out the structure of sponges characterised by the presence of filaments, and found that anatomically and histologically they do not differ from sponges which like *Euspongia* have never been found with filaments. To this statement I ascribe the highest importance. If the filaments have nothing to do with the skeleton, and if again there exist no deviations in histological structure of the corresponding sponges, which deviations, according to the law of correlation, ought to be expected, provided that filaments form a constituent part of their body, there are no grounds to consider them to be part of it. Whether they are algæ or fungi still remains questionable, but their nature as independent organisms is, I think, now clearly established. Schulze himself is also of this opinion, although, with his usual prudence, he states it rather conditionally. Notwithstanding, he is still inclined to ascribe to the presence of filaments a high systematic significance; he appeals to an analogous instance in the vegetable kingdom. He

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxxv. p. 112. [2] On *Velinea gracilis*, p. 445. [3] Revision, &c., part ii. p. 546.

says the lichens are also nothing but fungi and algæ together; still, they form a systematically independent subdivision, owing precisely to their double nature. I do not know whether botanists are right in separating systematically the lichens, but this question is of no consequence to us; I do not, however, believe the comparison just mentioned to be fortunate. The lichens represent an extreme instance of that kind of symbiosis which v. Beneden calls "mutualismus." The symbiosis of filaments with sponges is even not so much a commensalism as an indubitable parasitism. In the case of mutualism, the beings constituting the whole undergo such modifications in their structure that a separate existence becomes impossible. There are to be found no deviations in the organisation of sponges attacked by filaments, as compared with that of closely allied forms devoid of them. Microscopic preparations of *Hircinia variabilis* and *Cacospongia scalaris* show no differences apart from the presence and absence of filaments. There are, accordingly, absolutely no grounds for supposing that *Hircinia*, having got rid in some manner or other of filaments, would be no longer able to live. It is also quite obvious that the phenomenon under consideration is not commensalism, but parasitism. Beginning with forms like the Challenger specimen of *Cacospongia collectrix*, where filaments are represented but very scantily, we come through all possible intermediate stages to the forms which, as in the case of the Challenger specimen of *Cacospongia irregularis*, are so overloaded with them that the parenchyma is almost entirely replaced by these curious organisms; all this, now that the independence of the filaments is no longer doubtful, seems to me a decisive proof in favour of the opinion held for many years by Carter, that in the filaments we have really to do with nothing but parasites. This conclusion alters the matter. There are instances in which the diagnosis of parasites involves the mention of the host they inhabit. This does not occur, however, except in connection with certain modifications in the structure of the parasite, rendering it impossible for it to inhabit another host; but nobody would characterise the host systematically by reference to its parasites, and should we adopt the family of Hircinidæ as a family represented by forms with filaments in the parenchyma, we should be equally obliged to subdivide the species *Homo sapiens*, according to the presence or absence of *Tænia solium*, into two systematic groups. Hence I propose the dissolution of the family Hircinidæ, and the location of its representatives in other groups, according to more positive characters.

The question as to the nature of the filaments, whether plants or animals, is therefore beyond the domain of spongiology; but since it is of great general interest, I venture to communicate here what I was able to make out in this direction during the examination of the Challenger material. As to their structure, I must refer the reader to the statements of F. E. Schulze. I was able to discern all he has seen, but was unable —in spite of the excellent homogeneous immersion system ($\frac{1}{24}$) of R. Winkel—to make out anything more as to their organisation. The comparative size and shape of the heads

are shown in Pl. VIII. figs. 4 and 5. What I have to communicate concerns their origin, provided I am right in identifying the dumb-bell shaped bodies whose description will be given later on along with the filaments. Bowerbank, Schmidt, and Kölliker found in many of the specimens characterised by the presence of filaments certain round bodies, and it has been supposed by the last named naturalist that these bodies give rise to the filaments. F. E. Schulze, on the contrary, maintains that there can be no question as to any such connection; he finds these bodies too, but is inclined to consider them to be unicellular algæ, the more so as he has observed them in phases of division more or less complete. I am uncertain whether the bodies I am about to describe, which are represented on Pl. VIII. fig 2, are identical with those of F. E. Schulze and Kölliker. I believe them, however, to be so, since the corresponding description of Schulze is thoroughly applicable to them, and also because I found some of them on the point of dividing into two halves; but even if identical, I am yet more inclined to adopt the opinion of Kölliker, and to ascribe to them a certain connection with the filaments. I observed these round bodies in my *Cacospongia dendroides*, and comparing them with the heads of its filaments, was struck by their mutual resemblance. Not in every case, however; for, beginning with forms characterised by the thickness of their walls and indistinct central differentiation through numerous intermediate stages, I came to forms with walls far thinner, and, in their central contents, recalling very much the drawings Schulze gives of his conjectural algæ in *Hircinia* (*loc. cit.*, pl. iv. fig. 15). An attentive examination of their walls shows that they are provided with a small thickening, which appears to correspond exactly with the spot where the thread of the filament separates from its head. In a couple of cases, I think, I have also seen these bodies, when grown thin-walled, still in connection with the thread; but even if this were not an optical illusion, it seems to occur pretty seldom, and we have also to suppose that the further differentiation of the filamental heads—provided that they are identical with our round bodies—takes place only after the head has separated from the thread. The final phase of this development consists in the bursting of the wall so that the internal contents escape. It is represented by corpuscles which, when out of the capsule, present a great variety of size, some so small that they appear to be merely points, others so large that they are readily to be discerned by a magnifying power no higher than 200–250. In some cases these corpuscles appear to have linear or even fusiform outlines. This, however, is very rare; they almost always have a very definite dumb-bell shape, so that if such a body were to be imagined as growing in length a typical filament would result. But if this really occur, it apparently does not take place immediately, the corpuscles having the faculty of multiplying previously by division; sometimes, but not often, a cross division has been observed, sometimes a star-like one, sometimes a longitudinal one. As the result of this division, a new generation of corpuscles of the same form may again occur. As to their internal structure, I can state that, as in the filamental heads, their walls consist of concentric layers; a

certain differentiation in their centre is also to be discerned, but I am not sure whether this is not the result of an imperfect penetration of the staining fluid into their bodies. Their whole appearance is a "bacterian" one. So much I can state from actual observation. Induced by these observations, I was desirous of pursuing their conjectural transmutation into true filaments. I was, however, unable to accomplish this, and thus corroborate with decisive proof the statement as to the mutual connection of the round algæ-like bodies, the dumb-bell shaped corpuscles and the filaments. Can this be supposed nevertheless? When deliberating over the phenomenon theoretically, I was inclined to answer this question in the negative; for, as remarked before, the dumb-bell shaped corpuscles, having reached a certain size, show in most cases a tendency to multiply, which again cannot be denied with respect to the round bodies themselves. All this would be very strange, if we should identify the former with filamental heads and the latter with filaments themselves; and again, though I have seen single dumb-bell shaped corpuscles of comparatively very large size (0·06 mm.), I never saw them so large that one might regard them really as young filaments; while if they really undergo transformation into filaments, one would expect to find all possible intermediate stages. On the other hand, when examining the corresponding preparations, and comparing the round bodies with the filamental heads and the corpuscles with true filaments, I can give to the above question but one answer—a decided "Yes." But whatever be the fact, I consider it my duty to communicate in a most detailed manner what I have observed, and what may stand in connection with the origin of the filaments, hoping that my statements may be of help to any naturalists who may at some future time enter upon a special research into the nature of these enigmatical formations.

I turn now to a detailed discussion of the systematic value of the properties of the canal system. The diagnoses of the two types of canal system characteristic of Keratosa have been already given on pages 4, 5. It has been also stated that the properties of the canal system are in a certain sense antagonistic to those of the skeleton with regard to its composition either of homogeneous or heterogeneous fibres; and again, that according to this latter character the horny sponges do not admit of their subdivision into two main groups, since such a proceeding would have a certain phylogenetic signification inconsistent with the circumstance that the differences in the histological structure of the skeletal fibres of an *Aplysina* and *Euspongia*, and on the other hand of an *Aplysilla* and a *Spongelia*, are of a quantitative and not a qualitative nature. But, owing to the fact that *Aplysina*, through *Verongia* and *Luffaria*, is connected with true Spongidæ, and again that the genus *Aplysilla* is connected, as Vosmaer has lately shown, through *Velinea* with *Spongelia*, the canal system of the sponges first mentioned being constructed upon one type, that of *Aplysilla*, *Velinea*, and *Spongelia*, including other allied genera upon another, one would question whether the Keratosa can be subdivided precisely according to the structure of their canal system. This question is again to be answered in the

negative, and on grounds of exactly the same nature as those forbidding the subdivision of the Keratosa into Ceratina and Psammonemata, Carter, or Aplysinæ and Sponginæ, Hyatt. There is a striking difference between the canal system of *Aplysilla* and *Aplysina*. The flagellated chambers of the representatives of the genera *Aplysina* and *Verongia* (Pl. X. fig. 7) are small, pear-shaped, or rather hemispherical, each provided with one (?)[1] inhalent and one exhalent narrow canaliculus; and again, the surrounding ground-mass is so very rich in granules that the outlines of the cellular elements in the neighbourhood of the flagellated chambers are scarcely distinguishable. On the other hand, the flagellated chambers of an *Aplysilla* or *Ianthella* (Pl. II. figs. 4 and 5) are large and either of regularly elongated form (pouch-shaped) or of quite irregular outline; no special cameral canaliculi are to be discerned; the flagellated chambers receive the water from the subdermal cavities by means of numerous pores in their walls, and expel it by means of a large exhalent aperture; the surrounding ground-mass is clear and transparent. There are, however, amongst the horny sponges forms uniting these two extreme differences in every direction. As to the size of the flagellated chambers, in *Aplysina* or *Verongia* it is 0·02 mm. on an average, in *Euspongia* or *Cacospongia* 0·026 mm., in *Phyllospongia* 0·037 mm., in *Carteriospongia* 0·05 mm., in *Spongelia* 0·08 mm.; finally, in *Aplysilla* or *Ianthella* the flagellated chambers are still larger, reaching occasionally 0·15 mm. in length by 0·05 mm. and more in width; and it must be noticed—and this is very important—that in some Spongelidæ (comp. Pl. III. fig. 6) the flagellated chambers are again very small, their dimensions not exceeding those of the flagellated chambers of a typical *Euspongia*. Further, as to their form, we have a thoroughly similar series of connecting links. In the Aplysinidæ they are either pear-shaped or rather hemispherical, in the Spongidæ typically hemispherical, in the Spongellidæ more or less roundish, in the Darwinellidæ elongated. The same is also the case with respect to the presence or absence of special cameral canaliculi. While in Aplysinidæ each flagellated chamber possesses but one exhalent, and probably also but one inhalent, canaliculus, these canaliculi being comparatively long and narrow, in the Spongidæ they are short and broad, the inhalent system of each flagellated chamber being besides represented not by one but by three, four, or five canals, which sometimes are so very short that in many cases they can scarcely be properly regarded as special differentiations of the corresponding subdermal cavities. I refer the reader in this connection to the drawing of F. E. Schulze[2] and to my own drawing on Pl. V. fig. 3, and wish to add that in many, indeed exceptional but still numerous, instances I found in true Spongidæ the flagellated chambers devoid of any special *exhalent* canals, but just as is the case with the genus *Carteriospongia*

[1] This question F. E. Schulze (*Zeitschr. f. wiss. Zool.*, Bd. xxx. p. 398) leaves undecided. I also was unable to come to a decisive result with respect to *Aplysinæ* and *Verongia* owing to the inconvenience of these forms for certain manipulations, but so far in this respect as analogous forms like *Corticium*, *Chondrosia*, and *Chondrilla* are concerned, there can be no doubt that each flagellated chamber possesses but one inhalent canaliculus.

[2] *Zeitschr. f. wiss. Zool.*, Bd. xxxii. pl. xxxvi. figs. 11, 12.

(Pl. V. fig. 8), communicating with the subjacent exhalent cavities by means of a large exhalent opening. Finally, as to the question whether the ground-mass surrounding the flagellated chambers is full of granules or devoid of them; the more or less clear manifestation of this character appears to be in such a high degree dependent on other properties of the canal system that it may be said beforehand that we shall have in this respect a series of intermediate stages between *Spongelia* and *Aplysina* similar to that noticed with regard to the form and size of the flagellated chambers. As is well known, it has been stated by F. E. Schulze that (except in *Oscarella* (*Halisarca*) *lobularis*, which is, however, not a typical representative of the sponges with the canal system after Dr. Vosmaer's[1] 4th type) the ground-mass around the flagellated chambers has been found to be granular whenever the canal system shows a high degree of development in the direction of enlarging the surface washed by the water. But Schulze has also stated that, whenever the development of the canal system has reached its highest point (*Aplysina*, *Chondrosia*, *Corticium*), the ground-mass is literally over-loaded with granules; that further, whenever the canal system possesses a transition character (Spongidæ and particularly Plakinidæ), the granules are by no means so numerous; and, finally, that in the representatives of the genera *Spongelia* and *Aplysilla* the granules are not to be found at all. For my own part, I have been fortunate enough to investigate some forms which are, in this respect, a connecting link between the genera *Euspongia* and *Spongelia*. In *Phyllospongia*—whose flagellated chambers are, as before stated, approximately one and a half times as large as those of *Euspongia* or *Cacospongia*—I could observe the presence of the granules in question only with the help of the system No. 7 of R. Winkel;[2] in *Carteriospongia*—and in this form the flagellated chambers, although of the same shape as those of *Euspongia*, are comparatively much larger and at least in *most* cases devoid of special inhalent and exhalent canaliculi—the granules proved to be extremely few in number, and their presence could have been placed beyond doubt only by the system No. 10 of Winkel.[2] To sum up, we have, with regard to the structure of the canal system, a series of transitions quite analogous to those concerning the skeletal fibres, whether homogeneous or heterogeneous. Accordingly, the final conclusions must be also analogous one to another.

I may now summarise the foregoing observations. There have been discussed five systematic characters, and we came to the conclusion that two of them are absolute characters, the remaining three being only relative. We came also to the result that one of the first-mentioned, namely, the presence of filaments, is capable of no systematic application, and again, that so far as the second absolute character—I mean the presence of true cells in the walls of the skeletal fibres—is concerned, its systematic value cannot, in the present state of our knowledge, be defined.

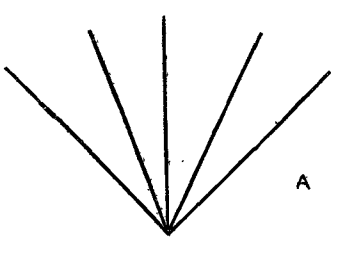
Of the three relative characters, one, the tendency to take in foreign bodies, only

[1] Ueber Leucandra aspera, *Tijdschr. d. Ned. Dierk. Vereen.*, Bd. v. p. 163.

[2] The objective No. 7 magnifies 275–700 diameters, No. 10, 500–1000 diameters, according to the eye-piece employed.

concerns the sponges with homogeneous skeletal fibres, and it has been stated that this character is of a very conditional nature, since the tendency in question is common to sponges of entirely different internal organisation. The properties of this latter, as well as those of the more detailed structure of the skeletal fibres, constitute the two other relative characters, and we have seen that, apart from the point that they are relative, they are also antagonistic to one another in a certain sense of the word. Such is the case with respect to the two characters to which, in the Keratosa, the highest systematic value has been repeatedly ascribed. The fact of their being relative does not permit us to make use of them in order to divide the group in question into two subdivisions, while this is demanded by their mutual antagonism. And yet these characters are undoubtedly the most important, the only characters according to which any main subdivisions may be realised, for they concern the structure of both the constituent parts of the organism of a horny sponge, and as to other systematic characters of the Keratosa, we shall soon see that they are unfit even for good generic distinctions.

What kind of arrangement can be adopted under such conditions? Dr. Vosmaer, as if in order to reconcile the contradictions in question, proposes[1] a subdivision of the group directly into families, characterising them by the properties both of the skeleton and of the soft parts. His arrangement will be adopted in the descriptive part of this paper, as no better arrangement seems at present possible; it is, however, an artificial one. By our systems we have to express the phylogenetic affinities of the corresponding animals, and the arrangement of Dr. Vosmaer does not express them. He subdivides the Keratosa into five families directly. How is this to be understood from a phylogenetic point of view? Are these five families divergent branches from the same spot of the general genealogical tree as represented by the diagram A? or do they form together the figure represented by the



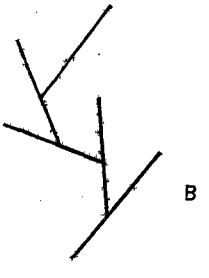


diagram B? There are no answers to these questions, and this is not the fault of Dr. Vosmaer, whose arrangement is at any rate the best of all others, for it pays attention to the characters both of the soft parts and of the skeleton; the matter itself is of a very

[1] On *Velinea gracilis*, p. 444.

ambiguous nature, since systematically the horny sponges present a kind of *circulus vitiosus*. Through *Luffaria* and *Verongia*, *Euspongia* is connected with *Aplysina*, but, on the other hand, it is also, through *Carteriospongia*, connected with *Spongelia;* now *Spongelia* through *Velinea* is connected with *Aplysilla*, and again *Aplysilla* through *Ianthella* is connected with *Aplysina*. It is evident that under such circumstances the families of Dr. Vosmaer are by no means natural systematic groups. With regard to the mutual relations of the genera of different families, such a *circulus vitiosus* is inconceivable, and proves only that such families are not natural. As I remarked before, I adopt the arrangement proposed by Dr. Vosmaer; to attempt a better one would, I believe, be at present premature; but I adopt it only as an arrangement of a provisional character.

The foregoing observations were begun in order to decide the question—Which of the existing systems of the Keratosa is the most to be recommended? The unexpected result at which we arrived is of such high importance that its further foundation becomes desirable, and as this latter demands a detailed discussion of characters used by classifiers as systematic distinctions between different representatives of our conjectural families, I now pass on to those of generic value.

II.—CRITICISM OF THE GENERA.

There are in Science two directly opposite opinions as to the question of what a genus ought to be. Some naturalists demand for the genus the presence of an absolute, qualitative distinction; others are satisfied with a distinction of a quantitative nature, and while, *e.g.*, Nägeli summarises his opinions as follows:—

"Für die generische Trennung scheinen mir folgende Bedingungen als unerlässlich bezeichnet werden zu müssen:

1. Uebereinstimmung im ganzen Verhalten, also innigere natürliche Verwandtschaft unter den Arten der einen und unter den Arten der anderen Gruppe,—und Differenz im ganzen Verhalten, also geringere natürliche Verwandtschaft zwischen den beiden Gruppen.

2. Mangel von Zwischenformen zwischen den beiden Gruppen;—die Arten der gleichen Gruppe können durch Uebergangsglieder verbunden sein oder nicht.

3. Vorhandensein von absoluten (nicht bloss von relativen) Unterscheidungsmerkmalen."[1]

In F. E. Schulze's paper on the Spongidæ[2] we find the following sentence:—"Besonders schwierig erscheint oft die Entscheidung der Frage, ob eine Anzahl verwandter Formen als Arten einer Gattung oder als Varietäten einer Art hinzustellen sind." Under such circumstances it is but obvious that the systematic literature of Keratosa, like that of all other groups, must be of a rather chaotic character. It is so. In the following passages I hope to clear up this chaos so far as the genera are concerned, and so far as this is necessary for the descriptive and some other more general purposes of this paper.

Family DARWINELLIDÆ.

It contains the following genera:—

Darwinella.

This genus was established by Fritz Müller[3] and characterised by him primarily by its horny spicules. There are no data in the literature of the subject as to the internal structure of the soft parts of the representatives of this genus; both F. E. Schulze

[1] *Sitzungsb. d. k. baier. Akad. d. Wiss.*, 1867, Bd. i. p. 168.
[2] *Zeitschr. f. wiss. Zool.*, Bd. xxxii. p. 612.
[3] *Archiv f. mikrosk. Anat.*, 1865, Bd. i. p. 344.

and Vosmaer, though inclined to place it systematically near *Aplysilla*, do so with great reserve, "provided that its internal organisation does not differ from that of other Aplysillidæ." I am in a position to authorise this proceeding entirely. Some time after having published his paper on this form, Prof. Schulze visited a Dalmatian Island, Lesina, and there dredged up specimens of a sponge which does not admit of even a specific distinction from *Darwinella aurea*, Fritz Müller. Prof. Schulze has been kind enough to hand me over these specimens for examination, and I can state that the internal organisation of *Darwinella aurea* follows on the whole the type, anatomical as well as histological, characteristic of *Aplysilla*. Accordingly, and in opposition to Dr. Vosmaer,[1] since the family name of Darwinellidæ was established by Merejkowsky[2] in the year 1878, that of Aplysillinæ, v. Lendenfeld[3] and Aplysillidæ, Vosmaer,[4] only in the year, 1883, I propose to return to the former name of the family in question. The genus *Darwinella* is a good one, its horny spicules differentiating it sharply from all other Keratosa.

Aplysilla, F. E. Schulze[5] (*Simplicella*, Merejkowsky[6]).

Lendenfeld[7] characterises this genus by its crust-like form and by numerous independent tree-like skeletal fibres,—a character common also to *Darwinella*. The distinction consists in the absence of spicules. This genus would be a good one only if united with the next under consideration.

Dendrilla.

Here v. Lendenfeld[8] finds the generic character in the property that the skeletal fibres do not stand separately as in *Aplysilla*, the whole skeleton presenting a single tree with numerous secondary, tertiary, and other branches. This distinction is, however, scarcely of generic consequence. In the Spongelidæ F. E. Schulze[9] has described a form (*Spongelia spinifera*), which differs from other representatives of the genus in the same direction, but even more than *Dendrilla* from *Aplysilla*; yet he merely placed it as a new species in his genus *Spongelia*. At any rate *Aplysilla* and *Dendrilla* show much closer affinities with one another than with *Darwinella* or *Ianthella*.

Ianthella.

This genus was established in the year 1869 by Gray,[10] as the representative of an independent family of horny sponges, and excited among naturalists a great doubt

[1] On *Velinea gracilis*, p. 444.
[2] *Mém. de l'Acad. d. Sci. de St. Pétersb.*, tome xxvi., No. 7, p. 44.
[3] *Zeitschr. f. wiss. Zool.*, Bd. xxxviii. p. 235.
[4] *Loc. cit.*, p. 443.
[5] *Zeitschr. f. wiss. Zool.*, Bd. xxx. p. 404.
[6] *Loc. cit.*, p. 43.
[7] *Loc. cit.*, p. 309.
[8] *Ibid.*, p. 270.
[9] *Zeitschr. f. wiss. Zool.*, Bd. xxxii. p. 152.
[10] *Proc. Zool. Soc. Lond.*, 1869, p. 49.

as to whether it is really a sponge. Flemming[1] and F. E. Schulze[2] have expressed such doubts; and Marshall[3] feels more inclined to regard it as an alga than a sponge. Amongst the Challenger specimens I find two forms which are well-marked representatives of the species *Ianthella flabelliformis*, and which are also distinct sponges with the canal system after the type of that of *Aplysilla* or *Darwinella*. The genus *Ianthella*, like *Darwinella*, is indeed a very good one, its chief generic character, viz., the presence of true cells between the horny laminæ of the skeletal fibres, being of an absolute nature, but it must be added that with respect to the conjectural family Darwinellidæ, this genus narrows the diagnosis of the family as given by Vosmaer (On *Velinea gracilis*, p. 477), the skeleton of its representatives being represented by fibres anastomosing with one another.

Family SPONGELIDÆ.

In the family Spongelidæ (I retain this name since the only one having the priority over it is derived from the still doubtful genus *Dysidea*) six genera have been hitherto distinguished, namely:—

Velinea.

We owe this curious genus to Dr. Vosmaer,[4] who places it in his family of Spongelidæ, notwithstanding that its skeletal fibres are, at least in many instances, obviously heterogeneous, but in accordance with its skeleton being represented by a network of anastomosing fibres; his Aplysillidæ, on the other hand, being characterised by a skeleton of tree-like shape. We have, however, learned that this latter character is not admissible. The skeleton of *Ianthella* is composed of anastomosing fibres, yet these latter are heterogeneous, and the whole internal organisation constructed upon the type of true Darwinellidæ. The fact is that *Velinea* is a connecting link between this latter family and Spongelidæ, and as such it is indeed a very interesting form, but, as an independent genus, belongs to those which from a systematic point of view are very ambiguous.

Spongelia, Dysidea, Psammascus.

In the year 1834 Nardo[5] subdivided his previous genus *Aplysina* into two subgenera, "*Aplysinæ velariæ*" and "*Aplysinæ spongeliæ*." In the year 1842 Johnston[6] created the genus *Dysidea* for his *Dysidea fragilis*, which, according both to O. Schmidt[7] and

[1] *Loc. cit.*, p. 6. [2] *Zeitschr. f. wiss. Zool.*, Bd. xxx. p. 381. [3] *Jahresb. d. zool. Stat. Neapel*, 1881, p. 161.
[4] *Mittheil. zool. Stat. Neapel*, Bd. iv. Heft. 4, p. 437. [5] *Isis.*, 1834, p. 714.
[6] British Sponges, &c., p. 185. [7] Spong.-Fauna des atlantisch. Gebietes, p. 27.

Marshall,[1] cannot be separated even specifically from *Spongelia pallescens*, Nardo. Notwithstanding, in England, the name *Dysidea* has not been given up, and in order to reconcile English and Continental naturalists, Marshall proposed to retain both these names in order to apply them to different forms. He groups Johnston's *Dysidea fragilis* in the genus *Spongelia* as restricted by F. E. Schulze, and, on the other hand, Bowerbank's species *Spongelia coriacea* and Hyatt's *Spongelia fragilis* in the genus *Dysidea*, giving it a new and detailed diagnosis, and in harmony with Hyatt—who four years before also retained both these genera, and even grouped them in different families on the ground of a thoroughly false supposition as to the manner of growth of the horny skeletal fibres—and, I repeat, in harmony with Hyatt, demands a more pronounced separation of both these genera. This latter view is expressed in a report on his own memoir on Dysideidæ and Phoriospongiæ,[2] while in the memoir itself (*loc. cit.*, p. 91) he seems to be of a rather different opinion, writing as follows: "Ganz scharf zu trennen sind diese genera freilich nicht, so wenig wie *Euspongia* und *Cacospongia*, diese und *Spongelia*." This is, however, of little consequence indeed, but unfortunately, on the whole, instead of having simplified the matter Dr. Marshall complicated it still more. The series of his Dysideidæ in the paper above mentioned he opens by the newly created genus *Psammascus*, characterising it by a great number of peculiarities, each of which, however, must be regarded as almost devoid of any systematic importance. This is also but of little consequence; it is not for the first time that in the Keratosa bad genera have been established and bad generic definitions given, but Dr. Marshall adds to the above definition the following remark: "Of all Dysideidæ this genus (*Psammascus*) shows the closest affinities to the genus *Spongelia*, being however to be readily distinguished from it by the presence of foreign enclosures also in the soft parts."[3] If now the reader will compare the definition Dr. Marshall gives of his genus *Psammascus* (*loc. cit.*, p. 92) with that by which he describes the genus *Dysidea* (*loc. cit.*, p. 98), he will find that this latter genus—apart from the character consisting in the presence of a skin containing numerous foreign enclosures and to be easily drawn off (a character of a very doubtful systematic consequence,[4] but for which nevertheless Dr. Marshall evinces the greatest predilection)—differs from *Psammascus* only in the presence of foreign bodies in the parenchyma; and, when I add, in harmony with F. E. Schulze,[5] that Dr. Marshall has been quite wrong in supposing the true representatives of the genus *Spongelia*, in the sense of F. E. Schulze, to be devoid of any foreign enclosures both in the parenchyma and in the dermal membrane; when I further mention that neither in Dr. Marshall's paper on Dysideidæ nor in the highly detailed and precise memoir on the genus *Spongelia* by F. E. Schulze are any statements to be

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxxv. p. 91.
[2] *Jahresb. d. zool. Stat. Neapel*, 1880, p. 178.
[3] *Zeitschr. f. wiss. Zool.*, Bd. xxxv. p. 92.
[4] Comp. F. E. Schulze's discussion of the question in *Zeitschr. f. wiss. Zool.*, Bd. xxxiii. p. 14.
[5] *Zeitschr. f. wiss. Zool.*, Bd. xxxii. p. 136.

found as to the question of whether the upper skin of the representatives of this latter genus is to be drawn off easily or not, and that this is due both to the state of preservation and to the number of foreign bodies in the dermal membrane; and when I finally lay stress upon the fact that Dr. Marshall makes no positive statements as to the internal structure of his genera *Psammascus* and *Dysidea*, so that these forms, like the species *Dysidea coriacea* of Bowerbank and *Dysidea fragilis*, Hyatt, perhaps all belong to the family of Spongidæ, or are to be distributed in different families of Spongidæ and Spongelidæ;—then the reader will see that after Dr. Marshall's paper the matter becomes comparable with the Gordian knot, which can no longer be disentangled but only cut asunder. This I perform in the following manner. I unite the genera *Psammascus*, *Dysidea*, and *Spongelia* into a single genus *Spongelia*, characterising it by *large* flagellated chambers—of course, as in the whole family, devoid of any special cameral canaliculi—and by the tendency to form "conuli."

Psammoclema.

This genus of Dr. Marshall[1] I adopt for the forms with *small* flagellated chambers and with the external surface smooth and devoid of any projections of the skin owing to those of the skeleton. All this is only of a temporary character; indeed, the possibility is not excluded that many good species, still undoubtedly allied amongst themselves, are all alike in the possession, for instance, of the character of forming cylindrical tubes with a well-developed central cavity, so that my species *Psammoclema vosmaeri* would have to be transferred into another new genus; but it must be remembered that in the group Keratosa all the present arrangements are but of a provisional character.

Psammopemma.

This genus, established by Dr. Marshall,[2] admits of a very sharp diagnosis. Among its representatives no horny skeleton is to be found at all, the propping apparatus of the sponge being represented by foreign enclosures exclusively. Moreover, the genus is perhaps really a good one, since, as suggested by Dr. Marshall, the possibility is not excluded that the sponges in question receive the foreign bodies in a way different from that in which they are obtained by other Spongelidæ (comp. Dr. Marshall's above-mentioned paper, p. 121). At any rate, this genus is to be referred to the Keratosa,[3] and according to the internal organisation of the soft parts to the Spongelidæ.

[1] *Loc. cit.*, p. 109. [2] *Loc. cit.*, p. 113. [3] For grounds, see p. 46.

Family Spongidæ.

The family of Spongidæ possesses a larger number of genera than any other family among the Keratosa, but it is only in Aplysinidæ that we meet with genera of such conditional characters.

Euspongia, Hippospongia, Cacospongia, Stelospongos.

The genus *Euspongia* has its own history. Established in the year 1859 by Bronn, it has been adopted by O. Schmidt, although not immediately. It was not adopted by Alpheus Hyatt, who returned to the old name of *Spongia*, auctorum, but has been again recalled by F. E. Schulze, although with a certain reserve. Prof. Schulze, though adopting this name as a generic one, still lays stress upon the fact that the genera *Euspongia* (which he characterises by fine skeletal fibres forming very small meshes) and *Cacospongia* (characterised by him as well as by O. Schmidt,[1] from whom it originates, by comparatively thick skeletal fibres and large meshes) are very closely allied to one another, and that with respect to some intermediate forms the question of whether the classifier has to do with a *Cacospongia* or *Euspongia* is to be decided only according to his individual opinion.[2] One might say that the matter is not so very complicated; one would believe that the *Cacospongiæ* and *Euspongiæ* are divergent branches of the general genealogical tree (in the sense that the skeleton presenting a supporting apparatus for the soft parts, one group of Spongidæ have adopted thick fibres and large meshes, the other fine fibres and small meshes, both kinds of skeleton being thus mechanically perhaps of equal strength), connected by the presence of all possible intermediate stages; that in some thousands of years, when the latter have died out, spongiology will have to deal with two very good genera. The matter is, however, by no means so simple, owing to the fact that each of these genera shows other special modifications, and the genus *Euspongia*, namely, in the direction which leads us to the genus *Hippospongia*, F. E. Schulze[3]; a *Cacospongia* in order to become a *Stelospongos*, O. Schmidt.[4] F. E. Schulze characterises his genus *Hippospongia* by the presence of a well-developed system of canals permeating the body of the sponge, often in such a manner that between them only comparatively thin partition-walls can be found, and further, by the absence of primary fibres which are directed in *Euspongia* and *Cacospongia* perpendicularly to the external surface, the latter character being in causal connection with the peculiarity first mentioned; the genus *Stelospongos* was established in 1870, and characterised by the differentiation of the skeletal fibres in separated columns directed in a more or less regular manner radially from the basis of the sponge towards the external surfaces, and consisting each of a compact network of vertical primary and horizontal

[1] Spong. d. adriat. Meer., p. 26.
[2] *Zeitschr. f. wiss. Zool.*, Bd. xxxii. p. 612.
[3] *Zeitschr. f. wiss. Zool.*, Bd. xxxii. p. 614.
[4] Spong. des atlant. Gebiet., p. 29.

secondary fibres, these latter also occasionally uniting the columns with one another, the fibres themselves being thick and hard. To the diagnosis given by F. E. Schulze of his *Hippospongia* I can add the following point, allowing an easy distinction to be made between the representatives of this conjectural genus, and concerning the character of the outer surface, though admitting of no examination of the outermost ends of the canals perforating the body of the sponge, but still betraying their presence by an alternation of thick and massive portions of the sarcode with spots where only very thin membrane covering the subjacent cavities is to be found. The drawing of my *Hippospongia anomala* given on Pl. VII. will illustrate my idea. This character, however, is only of practical importance. To sum up, both in *Stelospongos* and *Hippospongia* we have to deal with porous forms, the skeletal fibres of the first genus, however, admitting of a distinction into thick primary and finer secondary ones, those of the genus *Hippospongia* being on an average all of the same size and thickness; a good distinction indeed, and further, a typical *Stelospongos* has a quite different shape from that of a typical *Hippospongia*. But as stated before, the matter is by no means so very simple. As to the typical *Hippospongiæ*, I found many of them (all belonging to the species *Hippospongia equina*) in the collection of Prof. F. E. Schulze at the Zoological Institute of Graz, and I make use of this opportunity in order to express my great thankfulness to Prof. F. E. Schulze for his liberality; as to the typical *Stelospongos*, Prof. Steenstrup of Copenhagen has been kind enough to send me three specimens of it determined as *Stelospongos* by O. Schmidt himself. But together with these three specimens, Prof. Steenstrup sent me some other horny sponges (different varieties of Hyatt's *Spongia agaricina*, subsp. *dura*) distinguished also by radial columns as described before, the fibres constituting them being, however, all of the same dimensions; and again, in the Challenger Collection I find one specimen also of the same character, but with fibres thick and rigid, while those of Prof. Steenstrup's specimens just mentioned are fine and elastic. The skeleton of a typical *Hippospongia* has a rather different appearance from that of a typical *Stelospongos*,[1] but it is obvious that if the canals perforating the body of a *Hippospongia* were to assume a more regular disposition, we should have a skeleton in the form of numerous columns standing separately, which is so very characteristic of the genus *Stelospongos*. This is, as we have seen, the case both with regard to Hyatt's *Spongia agaricina*, subsp. *dura*, and again, atl east in a certain degree, with regard to the sponge of the Challenger Collection above alluded to. The first mentioned can indeed be still regarded as *Hippospongia*, the last mentioned, however, only if we enlarge the diagnosis of the genus *Hippospongia* in order to group into it forms with thick skeletal fibres. Neither is it *Stelospongos*, since its fibres do not admit of the distinction into primary and secondary ones. I ask, to which character

[1] Comp. Schulze's paper on Spongidæ, *Zeitschr. f. wiss. Zool.*, vol. xxxii. pl. xxxv. fig. 14, and Schmidt's Spongien des atlantischen Gebietes, pl. iii. fig. 13, and also my drawing Pl. VI. fig. 2.

have we to give the preference, to the differentiation of the fibres into primary and secondary ones, or to their thickness and rigidity? Through my *Hippospongia anomala*, and indeed many other still unknown forms, the genus *Euspongia* is very closely allied to the genus *Hippospongia;* through *Cacospongia mollior*, O. Schmidt, it is not less closely allied to the true *Cacospongiæ;* both *Cacospongia* and its special modification the genus *Stelospongos* being connected with typical *Hippospongiæ* by means of forms similar on the one hand to my *Cacospongia intermedia*, and on the other to *Stelospongos friabilis* and *Spongia agaricina*, subsp. *dura*, Hyatt. The reader sees that in these genera we meet the same *circulus vitiosus* as in speaking of the mutual affinities of different families of the group Keratosa, and that the classifier in numerous cases has no other guidance than his own individual opinion. A quite analogous phenomenon we find also with regard to the next genus.

Coscinoderma.

This genus was created in the year 1883, and defined by Mr. Carter,[1] by many characters of which, however, only one can claim the designation of a generic one, namely, the uniformity of the skeletal fibres as in *Hippospongia*, these fibres not admitting of the distinction into primary and secondary ones, being all of the same thickness, and not forming polygonal meshes but such as may be compared with wool-whorls. Of course the system of internal canals, so very characteristic of *Hippospongia*, is not to be found here. Mr. Carter established his genus for only one species, *Coscinoderma lanuginosum*, and characterised it, *inter alia*, by a specially differentiated dermal membrane full of foreign bodies, the fibres of the skeleton being almost free from any enclosures, and by the evenness of the external surface. In the Challenger Collection I find a specimen with the dermal membrane, like that of *Coscinoderma lanuginosum*, full of foreign enclosures, and in general, apart from the colour of the skeletal fibres, just of the same properties as the above-mentioned species, with very fine skeletal fibres, and forming no polygonal meshes. But the outer surface of this specimen proved to be uneven, owing to the sharp-pointed denticulations of the skeleton. Further, I find a specimen whose dermal membrane cannot be easily drawn off, whose skeleton meshes are polygonal, but which shows on the surface of its skeleton the same denticulations, corresponding with sharp-pointed networks of the skeletal fibres, precisely as in the specimen I have just spoken of, but whose fibres are all of the same thickness, their colour—of a paler shade in the specimen before mentioned—being, as in *Coscinoderma lanuginosum*, rather brownish, and almost entirely devoid of any foreign enclosures. And finally, I find a specimen quite different from those before mentioned in its external shape, with fibres cored with foreign bodies, but still all of the same thickness. Are all these forms really so closely allied to one another as to be united into one genus?

[1] *Ann. and Mag. Nat. Hist.*, ser. 5, vol. xii. p. 309, 1883.

Phyllospongia, Carteriospongia.

The first of these genera was created by Ehlers,[1] the second by Hyatt;[2] both have been united by the last-named naturalist into a special family Phyllospongiadæ, characterised by the leaf-like shape of its representatives, those of the genus *Phyllospongia* being lamelliform and with the external surface quite smooth, those of the genus *Carteriospongia*, though still lamelliform, very often indeed provided with numerous lateral outgrowths, but far thicker, and probably in physiological harmony with this latter peculiarity, with the outer surface presenting on its whole extension an alternation of more or less deep elongated hollows, and more or less high, also elongated, tubercles. I also think that both these genera are closely allied to one another, but this is only my individual opinion, for while the skeletal fibres of *Phyllospongiæ*, thin and elastic as they are, recall those of *Euspongia*, the skeletal fibres of *Carteriospongia*, far thicker than the preceding and overcharged with foreign enclosures, resemble those of *Cacospongia*, the possibility is not excluded that the *Phyllospongiæ* are modified *Euspongiæ*, the *Carteriospongiæ*, on the contrary, modified *Cacospongia*. It may be further stated that the natural systematic place of *Carteriospongia* is among the Spongelidæ (comp. p. 17), while *Phyllospongia* as regards its internal organisation belongs to the Spongidæ. On the other hand, the chief point concerning their external shape seems to be also of a rather ambiguous nature, owing to the great variability of the form of the body in the group Keratosa, and particularly of the true Spongidæ. And it is very possible that though O. Schmidt[3] united *Spongionella*, Bowerbank, with his *Cacospongia*, the species *Spongionella pulchella*, Bowerbank, instead of being a British variety of *Cacospongia scalaris* as Schmidt supposes, is merely a link connecting the true Spongidæ with *Phyllospongia*. At least the figure of *Spongionella pulchella* given by Bowerbank in his Monograph[4] recalls very much that of *Spongia* (*Phyllospongia*) *papyracea* in Esper's Pflanzenthiere, the only distinction consisting in the comparative thickness of specimens which are leaf-like in both cases; and, on the other hand, it must be noticed that as to the second species of *Spongionella* described by Bowerbank (*Spongionella holdsworthii*), Carter[5] identifies it directly with *Spongia papyracea*, Esper. To sum up,—the affinities of both the genera I am speaking of are surrounded by no less uncertainty than those of the genera *Euspongia*, *Cacospongia*, &c., the generic distinctions being of the same conditional character.

Oligoceras, Hircinia, Ceratella.

The genus *Oligoceras*, established by F. E. Schulze[6] for some specimens from Lesina, is indeed one of the worst genera. Marshall[7] classes it under his Dysideidæ, and this

[1] Die Esper'schen Spongien, p. 23.
[2] Revision, &c., vol. ii. p. 540.
[3] Spong. d. adriat. Meer., Bd. ii., Suppl., p. 9.
[4] Vol. iii., pl. lxv. fig. 5.
[5] *Ann. and Mag. Nat. Hist.*, ser 4, vol. xvi. p. 193.
[6] *Zeitschr. f. wiss. Zool.*, Bd. xxxiii. p. 34.
[7] *Ibid.*, Bd. xxxv. p. 92

proceeding would have been as natural and comprehensible had it taken place before the classical investigations of F. E. Schulze were published, as it is strange now, Dr. Marshall's paper in question having been issued in the year 1881. Dr. Vosmaer[1] places this genus in his and F. E. Schulze's family Hircinidæ, another proceeding which would be quite inexplicable, since the species of *Oligoceras* hitherto described is entirely devoid of any filaments, had it not a very simple explanation, that of an erratum. Schulze himself lays great stress on the close affinity of *Oligoceras* with *Cacospongia*, and indeed, since in its somewhat absolute character (I speak of that of the canal system) the genus thoroughly agrees with other Spongidæ, and differs from *Cacospongia* only by secondary and therefore extremely conditional characters, its natural systematic place is near *Cacospongia*. The differentiating characters above mentioned are the following: (1) the tendency to take foreign bodies into the parenchyma, and particularly on to the external surface; (2) the want of a proper network of horny fibres, the horny substance being developed so scantily that portions of the body as large as peas are completely devoid of any skeletal fibres; (3) the structure of the skeleton, its fibres being overcharged with foreign enclosures, and the skeleton on the whole being represented by isolated fibres which have only rare anastomoses and ramify widely like the antlers of a stag. Do these characters together justify the establishment of a genus, even from the naturalist's point of view, not demanding for generic distinctions differences of an absolute nature? I see, logically at least, no grounds for answering this question in the negative, since one may regard the Oligoceratidæ as a group of forms with a tendency to lose the horny skeleton entirely in order to become Myxospongidæ, or at least analogues of *Psammopemma* among the Spongidæ. *Oligoceras* has accordingly the same right to exist as a genus as *Cacospongia* or *Hippospongia*, each personifying a new principle, all being connected amongst themselves by all possible intermediate stages. From this point of view I should be obliged to adopt F. E. Schulze's genus in question; I cannot, however, do so on account of the unusually conditional nature of the characters distinguishing the Oligoceratidæ, apart from the point that the transformation of a true *Cacospongia* into a not less typical *Oligoceras* appears to be very easily realisable (comp. p. 84). The characters separating *Cacospongia* and *Euspongia* from one another are also conditional, but in this latter case at least a conventional boundary is admissible. We can, if necessary, group in *Euspongia* forms with fibres not thicker, and with meshes not larger, than a given dimension, the forms with larger meshes and thicker fibres being grouped in the genus *Cacospongia*. But even a similar, quite artificial boundary is not applicable to the distinctions between *Cacospongia* and *Oligoceras*. All Spongidæ take foreign bodies into the parenchyma as well as into the skeletal fibres, and F. E. Schulze[2] himself warns us not to ascribe to this character too great a significance. But apart from this, even did the taking in of foreign bodies represent the manifestation of an "unknown intellectual power," and were their

[1] On *Velinea gracilis*, p. 445.

[2] *Zeitschr. f. wiss. Zool.*, Bd. xxxiii. p. 14.

number and quality thus characteristic of every sponge and not dependent on the peculiarities of the surrounding soil, it would still be practically impossible to distinguish *Cacospongia* from *Oligoceras* by these characters alone. And the third additional character of the latter would be also of very little assistance. The skeleton of *Cacospongia* is represented by a continuous network of fibres; that of *Oligoceras* is interrupted by spaces of parenchyma devoid of any skeleton, so that, on the whole, its chief fibres show a tendency to free themselves, to separate from one another in order as is the case with *Aplysilla*, and to form tree-like formations. But this character, or rather tendency, is common to all Spongidæ with skeletal fibres overcharged with foreign enclosures; in my *Cacospongia spinifera* and *Cacospongia tuberculata*, amongst fibres forming obviously a continuous network, I find fibres whose secondary ramifications do not reach the neighbouring primary fibres, so that a small tree is actually formed. In *Spongelia spinifera* F. E. Schulze[1] found a form with a still more pronounced tendency in its skeletal fibres to ramify, to lose connection with one another in order to form small tree-like structures. He did not, however, create for it a special genus. Again, as before alluded to, the conjectural generic characters of *Oligoceras* seem to be of a very unstable nature, and this is the second ground why the genus *Oligoceras* should not be adopted even provisionally.

The genus *Halispongia*, Bowerbank, being according to O. Schmidt identical with his *Cacospongia*, the genus *Ditela*, O. Schmidt, having been given up by Schmidt himself, who pointed also to the necessity of the same proceeding with respect to the genus *Auliscia*, Bowerbank, there remain only the genera *Hircinia* and *Ceratella* to be mentioned, since the names *Stematumenia*, Bowerbank, *Polytherses*, Fonbressin and Michelotti, and *Filifera*, Lieberkühn, are synonyms of *Hircinia*. The subgenus *Sarcotragus*, established by O. Schmidt in the year 1862, was abandoned by him in the following year.

As to the genus *Hircinia*, the reasons why I cannot adopt the family Hircinidæ in the sense of F. E. Schulze and Vosmaer have been stated in the foregoing pages (pp. 12–14), and indeed the grounds above mentioned which forbid us to use the presence of parasites in order to characterise the family, also forbid the use of this character for purposes of generic distinction. It is not without interest that amongst the Challenger specimens I have forms attached by filaments, some of which, according to their other properties, I must group in the genus *Stelospongos*, others in the genus *Oligoceras*, had it been retained, and others in the genus *Cacospongia*. Should we adopt the name *Hircinia* for forms with very large meshes and with fibres overcharged with foreign enclosures as Carter and Hyatt have done? I think this would be a very doubtful proceeding; the above characters are also common to *Oligoceras*, and we have

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxxii. p. 152.

seen that this genus cannot be adopted. The best thing that could be done would consist in a total disuse both of *Oligoceras* and *Hircinia*.

Finally, as to the Ceratelladæ, I regard their nature as sponges insufficiently proved to speak here of their place in the system. The late Dr. Gray,[1] to whom we owe the first description of these interesting beings, though classing them among the sponges, did so with the greatest reserve, "until their organisation and growth is known. At the same time," he adds, "I know no group of sponges with which they can be compared" (*loc. cit.*, p. 576). In his paper on the "Transformation of an Entire Shell into Chitinous Structure,"[2] Carter comes to the conclusion that the Ceratelladæ have absolutely nothing to do with sponges. He adopts both the genera distinguished by Gray in his family of Ceratelladæ, but he groups them in that of Hydractiniæ. Hyatt[3] is again of quite a different opinion on the matter. He considers the forms in question to be indubitable sponges, and, rejecting Gray's genus *Dehitella*, unites all the Ceratelladæ known to him in the single genus *Ceratella*. Now, so far as my own information goes—and like that of the naturalist before mentioned it is limited to the properties of the skeleton exclusively—I must confess that I can only agree with Mr. Hyatt. There is really in the skeleton of *Ceratella* nothing hydroid or coral-like; "on the contrary, the whole is thoroughly sponge-like." But this opinion can only be scientifically endorsed after an investigation of the structure of the soft parts of the animals in question, and, until we are acquainted with their internal organisation, any discussion as to their systematic place would be premature.

Family Aplysinidæ.

Apart from the genus *Dendrospongia*, Hyatt, which, if really to be adopted as an independent genus, may belong to the Darwinellidæ, the family in question contains the genera *Luffaria*, *Verongia*, and *Aplysina*.

Luffaria.

This generic name originated with Duchassaing de Fonbressin and Michelotti,[4] who have described under this designation numerous sponges from the Caribbean Sea. How far these sponges really belong to *Luffaria*, and not to *Verongia* or even *Aplysina*, is very difficult to say, the descriptions of these authors being very superficial. As a matter of fact, it must be stated that they regard the *Spongia fistularis*, Linné—illustrated in Esper's Pflanzenthiere (Bd. ii. pls. xx., xxi., xxiA.), and the specimen represented on pl. xx. is still in the Museum of Erlangen—as belonging to their newly-created genus

[1] *Proc. Zool. Soc. Lond.*, 1868, p. 575.
[2] *Ann. and Mag. Nat. Hist.*, ser. 4, vol. xi. p. 1.
[3] Revision, &c., ii. p. 550.
[4] Spongiaires, &c., p. 59.

Luffaria. Now, since for forms like *Spongia fistularis* the name of *Verongia* had been proposed by Bowerbank many years before, Hyatt, in the year 1875, rejected[1] the name *Luffaria* as identical with *Verongia*. It may be so with respect to the *Luffaria* of de Fonbressin and Michelotti, but Mr. Hyatt was wrong in not paying attention to the proceeding of O. Schmidt,[2] who in the year 1870 adopted *Luffaria*, and furnished the genus with a tolerably distinct diagnosis. He states that *Luffariæ* are sponges with skeletal fibres resembling those of a *Cacospongia* but still differing from them chiefly in three respects:—by a glass-like ("glasig") character of the fibres, by their faculty of splitting easily, and by the possession of a narrow central canal, not identical, however, with that of the true Aplysinidæ. This latter statement Schmidt illustrates by a drawing representing a fibre of a *Luffaria* highly magnified. To these three characters O. Schmidt appends a fourth concerning the structure of the network formed by the fibres. He ascertains that the fibres of *Luffariæ* are approximately all of the same size, *i.e.*, comparatively thick, and that the irregular network formed by them terminates peripherally not with an even surface but with a surface roughened by many prominent fibres, so that a portion of the skeleton if devoid of soft parts would represent something comparable to a brush. In the Challenger Collection I find two specimens, the properties of whose skeletal fibres agree with those of *Luffariæ* as described and illustrated by O. Schmidt. I found, however, that the network of their skeletal fibres, though ending peripherally in projecting fibres (Pl. IX. figs. 2 and 4), is composed not of fibres of one kind, as suggested by Schmidt, but of two kinds, of larger fibres all approximately of the same thickness and of smaller ones originating from the first mentioned, but differing from them not only in diameter but also in their histological structure, the central canal of many of these smaller fibres having been found to be inconspicuous. Whether my specimens are to be regarded as deviating forms, or whether the statement of O. Schmidt was based on an insufficient study of the skeleton of the *Luffariæ* which he had for examination, I am not prepared to say. I must add, however, that this last supposition seems to me to be very plausible, not only because the later spongiological papers of O. Schmidt do not show that attention to practical details so characteristic of his "Spongien des adriatischen Meeres," but also because a portion of the skeleton at least of the Challenger *Luffariæ*, when washed and dried, demands a microscopic examination in order to prove the presence of finer fibres, these latter being not only of a paler colour than the larger ones, and covered by them almost throughout, but also very scantily developed near the external surface. At any rate, I see no grounds for rejecting the genus in question. Thanks to the great amiability of Prof. Selenka of Erlangen, the type specimen of *Spongia* (*Verongia*) *fistularis*, Esper, has been placed at my disposal, and thus I am able to state that the difference between *Luffaria* and *Verongia*—which latter genus differs from *Aplysina* only by the compara-

[1] Revision, &c., vol. i. p. 401.

[2] Spong. d. atlant. Gebiet., p. 30.

tive thickness of the horny walls of its fibres—is greater than that between *Verongia* and *Aplysina*.

Verongia.

On page 7 I have stated the grounds which make it, though not very probable, yet not impossible, that the *Luffariæ* have perhaps nothing to do with Aplysinidæ, being only specifically modified *Cacospongiæ*. At any rate—though bearing in mind the necessity for certain concessions to the present state of our knowledge, we must necessarily place the genus in the family Aplysinidæ—the genus, owing to the fact that many of the smaller fibres of the skeleton of some of its representatives must be called homogeneous, is so very closely connected with true *Cacospongiæ* that its diagnosis can only be of a very conditional character. The same must be said with respect to the mutual relations of the genera *Verongia*, Bowerbank,[1] and *Aplysina*. Hyatt characterises his Aplysinidæ "by the regular net-like anastomosis of the fibres, the tendency of this to occur in the same plane, the flatness of the fibres, and the thinness of their walls."[2] He characterises his Dendrospongiadæ, of which the genus *Verongia* is a representative, "by the irregular anastomosis of the fibres of the skeleton, by their rotund form, and by the thickness of the horny walls."[3] As to the regularity or irregularity of the network of the skeletal fibres, the conditional nature of this character is but too evident;—it is well known what approximate expression geometrical outlines find in organised beings; again, as to the flatness of the fibres of Hyatt's Aplysinidæ, this character seems even more doubtful. F. E. Schulze has not only ascertained that the fibres of *Aplysina aërophoba* are all more or less mathematically cylindrical and their transverse section circular, but has also made it probable that the above-mentioned statement of Hyatt is due to the circumstance that the specimens he had for examination were dried, in which state all thin-walled round tubes filled with a fluid mass shrink, and form compressed tubes with transverse sections of elliptical outline.[4] Finally, so far as the comparative thickness of the fibre-walls is concerned, many of the foregoing lines have been written precisely to show that there are thick-walled fibres which show a tendency to become thin-walled, and again, in the *Aplysinæ*, fibres with the contrary tendency; we see therefore that the three characters in question—provided that Hyatt is correct as to the conjectural flatness of the skeletal fibres of the Aplysinidæ—are of a thoroughly conditional nature.

Aplysina.

The diagnosis of this genus having been already given when speaking of the preceding genus, all existing genera of the Keratosa have been presented to the reader, and I

[1] Monogr. of Brit. Spong., vol. i. p. 209
[2] Revision, &c., vol. i. p. 404.
[3] Revision, &c., vol. i. p. 400.
[4] *Zeitschr. f. wiss. Zool.*, Bd. xxx. p. 399.

have only to summarise the foregoing observations. I do it in the following words :— *with the exception of the genera Darwinella, Ianthella, and Psammopemma, all genera are devoid of any properties separating them absolutely from one another.*

The further conclusions deducible from this statement will be given in the last part of this Report, for they will only be instructive when we shall have learned the properties used at the present time in order to distinguish and characterise the species. An abstract discussion of all such properties would lead me too far; it is besides unnecessary, since the following chapter, devoted to the description of the forms brought home by the Challenger Expedition, may serve as a better illustration of them than any however detailed but abstract discussions. Some remarks with respect to the external character of the following descriptions: as in my memoir on the Challenger Calcarea, the reader will not find any specific diagnoses; I must confess I regard them in most cases as a loss of space and time, and altogether superfluous, especially as nearly every species in the Challenger Collection of Keratosa is represented by a single specimen only, so that the tendency to vary could not be made out. As to this question in general, I refer the reader to the extremely instructive paper of Heincke on the varieties of the herring[1]; on the other hand, I invite him to peruse the diagnoses of Calcarea given by Haeckel in his "Kalkschwämme" for every species. Would he receive any idea of the animal from a similar diagnostic description? I think not. And this with respect to Sponges, the geometrical properties of whose spicules present far more tenable systematic distinctions than is the case with regard to the Keratosa. As to those described in this paper, I regard their entire descriptions as diagnoses, and end this chapter with the following observations of a practical nature.

All the specimens in the collection not devoid of soft parts have been examined with regard to their canal system and skeleton. The skeletal fibres have been examined both in spirit and mounted in Canada balsam, after previous treatment with ammonia, in order to remove the soft parts. These latter have been examined in sections stained in different ways by different staining fluids; for it must be stated that while for the Calcarea no other staining fluid but picro-carmine is to be recommended, the matter is quite different with regard to the Keratosa, so that in each case the investigator must proceed experimentally.

[1] Die Varietäten des Herings, Berlin, 1877.

III.—DESCRIPTION OF THE SPECIES.

Group KERATOSA, Grant, 1861.

Ceraospongiæ, O. Schmidt, 1862.
Euspongiæ, Duchassaing de Fonbressin and Michelotti, 1864.
Ceratina and *Psammonemata* (*e. p.*), Carter, 1875.

Porifera with horny skeleton devoid of proper spicules.

Family DARWINELLIDÆ, Merejkowsky, 1878.

Aplysinidæ (*e. p.*), F. E. Schulze, 1878.
Aplysillinæ, v. Lendenfeld, 1883.
Aplysillidæ, Vosmaer, 1884.

Keratosa with large pouch-shaped flagellated chambers communicating by means of numerous pores on their walls with inhalent cavities, by means of one wide mouth with exhalent cavities; ground-mass without granules, transparent; axis of fibres thick.

Ianthella, Gray.

Verongia (*e. p.*), Ehlers.

Darwinellidæ, the fibres of whose skeleton contain true cells.

Ianthella flabelliformis, Pallas, sp. (Pl. I.; Pl. II. figs. 1–7).

Spongia flabelliformis, Pallas, Elenchus Zoophytorum, p. 380.
Ianthella flabelliformis, Gray, Proc. Zool. Soc. Lond., p. 49, 1869.
Verongia flabelliformis, Ehlers, Die Esper'schen Spongien, p. 11.

This species is represented in the Challenger Collection by two specimens both from the Eastern Coast of Australia; one of them may be seen drawn of natural size on Pl. I. Their shape, in accordance with the specific name of the animal, is that of a thin leaf terminating in a short stem; which latter in both cases is of irregularly cylindrical outline and about 25 mm. long by 12 mm. broad.

The Skeleton.—The constituent elements of the leaf-like part of the skeleton admit

of a distinction into primary fibres, taking their origin from the upper end of the stem in order to assume a radial direction, as can be seen on pl. xiii. of Esper's Pflanzenthiere, ii., and into secondary fibres uniting the primary ones with one another both perpendicularly and parallel to the surfaces of the sponge. Both the surfaces are uneven, and this is due to the circumstance that the secondary fibres, which are nothing but lateral branches of the primary ones, interlacing amongst themselves, form prominent irregular networks. The last-named are most fully developed near the upper end of the stem, growing gradually lower towards the edge of the leaf-like part of the animal. The external surface of this stem is comparatively smooth; its skeleton admits of no distinction into primary and secondary fibres, the whole presenting a very compact and solid network, with meshes of smaller diameter than those of the leaf-like extension (Pl. II. fig. 3). The fibres themselves, as is well known, are heterogeneous and, on the whole, to be classed as thick walled. The microscopical structure of the central pith-substance does not differ from that of *Aplysina*, as described by F. E. Schulze[1] in the case of *Aplysina aërophoba*, nor do the walls surrounding this central differentiation, and presenting, as is always the case, many layers of concentrically disposed horny laminæ, with the sole distinction that between these latter true cells are to be found in abundance. As to the histological properties of these interlaminar elements, I refer the reader to Dr. Flemming's[2] paper on *Ianthella*, for I can confirm all his statements except as to the ends of the fibres being, as he suggests, devoid of cells. For my own part, I could always discern them even on the youngest fibres, viz., on the fibres with only a very thin horny envelope, and am able to state that they are absent only at the ends of developing fibres, represented by pith-substance surrounded immediately by spongoblasts. That the cells enclosed in the walls are nothing but transformed spongoblasts is beyond doubt, but of course this will be actually proved only when direct observations on the actual process of development of the fibres in question have been made. For myself, amongst the elongated spongoblasts, as I have drawn them on Pl. II. fig. 5, I have very often seen cells of a more massive and also compressed form, and I believe these to be intermediate stages between the typical spongoblasts and the interlaminar cells. But I have not figured them, because their deviating appearance may yet be ascribed to the influence of the preserving fluid. Around the "mantle of spongoblasts" of young fibres I always found aggregations of mesodermic cells, though by no means always disposed parallel to the developing fibre as drawn and described by v. Lendenfeld[3] in his *Dendrilla rosea* and *Dendrilla aërophoba*. Around old fibres I have missed them completely. According to Flemming, the colour of the fibres of *Ianthella basta*, so far as the horny substance of their laminæ is concerned, is yellow, that of the enclosed cells deep violet. I have found in most cases the colour of the laminæ also to be violet. I am, however, inclined to ascribe this merely to the

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxx. p. 401, pl. xxii. fig. 11.
[2] *Würzburg Verhandl.*, N. F., Bd. ii.
[3] *Zeitschr. f. wiss. Zool.*, Bd. xxxviii. p. 286; pl. xiii. figs. 25, 28, 29.

influence of preservation in alcohol. I think that the colouring substance, by which the spongoblasts (if not all the cells of *Ianthella*) are coloured in the living state, is soluble in spirit, and might thus when dissolved have coloured the true horny substance also; for, while I found most of the fibres of a violet colour, and containing violet cells, I found also fibres whose cellular elements were of a deeper colour than usual, and that of the horny laminæ considerably paler.

The Soft Parts.—As to the anatomy of its soft parts, the species differs but little from *Aplysilla*, *Dendrilla*, and *Halisarca dujardini*. Both the surfaces of the sponge when examined with the naked eye show a great number of groups of openings, as represented on Pl. II. fig. 1, under a low magnifying power. These are the oscula, each being usually represented by four or five apertures. The parts of the membrane between them, when seen under the microscope, show themselves as usual to be provided with numerous minute pores. The water entering through these *pori dermales* reaches the cavities under the covering membrane, and passes from these latter by means of *pori camerales* into the flagellated chambers, in order to be expelled through a large mouth into exhalent canals, finishing with the oscula above mentioned. Thus each osculum, with its pores and its subdermal or inhalent cavities, flagellated chambers, and exhalent cavities, presents an independent whole, which may be compared with a state in a federal republic. The inhalent and exhalent canals are of very irregular outline; they may be very large and short, very narrow and long, &c.

The form of the flagellated chambers is also very variable. Its mathematical mean shape is expressed by the two flagellated chambers on Pl. II. fig. 5. But though such regular pouch-shaped flagellated chambers may be found without difficulty, the outlines of most others are quite irregular (comp. Pl. II. fig. 4). Sometimes they are cylindrical and elongated, sometimes irregularly roundish, often provided with secondary ramifications; their size is inconstant.

Now so far as the histological structure of the present species is concerned, it is constant to the general type prevailing among the Keratosa, presenting, however, a few new peculiarities. The ectodermic pavement-epithelium could be discerned only on the surfaces of the inhalent canal system. My endeavours to make it out on the external surfaces were unsuccessful, owing probably both to the state of preservation and to the fact that the external surfaces above mentioned are covered by a thin cuticle such as Schulze[1] has described in *Cacospongia cavernosa*. No distinction can be detected between the ectodermic and endodermic pavement-cells. In all cases they are flat, irregularly polygonal, with a comparatively small nucleus, and showing the protoplasmic granules only around the nucleus. As to other representatives of the endoderm, viz., flagellated cells, they seem to agree as regards their form with those of *Aplysilla*,[2] but it must be noticed that the flagellated cells are very sensitive to every method of preservation,

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxxii. p. 654.

[2] *Ibid.*, Bd. xxx., pl. xxiii. fig. 26.

and that their properties can be studied with success only in the living state. The constituent parts of the mesoderm are as usual represented by a transparent ground-mass, by stellate or fusiform cells and cellular elements of amœboid character. The amœboid cells differ from the first-mentioned apart from their general shape by their nucleus being comparatively larger. It is generally accepted that the amœboid cells in the sponges give origin to the generative products; both the specimens of *Ianthella* proved, however, to be sterile; in one of them, indeed, I found here and there large egg-shaped bodies, but since I did not succeed in discerning in them anything like a nucleus, I am far from being sure whether they were really ova or something else. The stellate mesodermic cells, as well as those of fusiform shape, do not differ from those of *Sycon raphanus* as described by F. E. Schulze,[1] but it must be said that while their fusiform modification is very seldom found in *Sycon raphanus* and the Calcarea generally, it is far more common in *Ianthella* than the stellate form. Particularly near the outer surfaces these fusiform, probably contractile, cells are very numerous, surrounding in rows the pores and oscula (Pl. II. fig. 6). I have spoken of them in their special modification as spongoblasts before, and it only remains for me to mention the interesting hypodermic elements, without entering upon the discussion of the question as to whether they are really modified stellate and not amœboid cells. At any rate they are larger than both the stellate and the amœboid ones, and their protoplasm is far richer in granules. It is indeed difficult, when seeing these elements lying separately amid fusiform muscle-cells (as drawn on Pl. II. fig. 6), to resist the idea that these elements are of a nervous nature, and their histological properties, so far as they could have been studied from the material preserved in alcohol, agree tolerably well with what we regard as typical nerve-cells. I must say, however, that I was unable to discern any connection between them and the fusiform cells, and on the whole consider their nervous nature to be as doubtful as that of certain mesodermic cells described by Sollas[2] in *Thenea muricata*, as well as that of the anastomosing "Stränge" discovered by F. E. Schulze[3] in the Spongidæ. I believe these cells to be equivalent to the gland-cells stated by v. Lendenfeld[4] to be present in his South Sea Aplysinidæ, and five years before by Merejkowsky[5] in his *Halisarca* (*Oscarella?*) *schulzei*. I have found similar cells in *Aplysilla sulphurea* and *Darwinella aurea*, and I am the more inclined to compare the enigmatic elements of *Ianthella* with these gland-cells, since, as I remarked before, the external surface of this sponge is covered by a thin cuticle. Of course they are larger than common spongoblasts, while the gland-cells of v. Lendenfeld agree with these latter both in shape and size, but this difference seems to me to be of no great importance. The best methods for rendering these, as well as hypodermic fusiform cells, visible are eosine and gold, for which latter the alcohol must be previously extracted.

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxv., Suppl., p. 253.
[2] *Ann. and Mag. Nat. Hist.*, ser. 5, vol. ix. p. 446.
[3] *Zeitschr. f. wiss. Zool.*, Bd. xxxii. p. 629.
[4] *Ibid.*, Bd. xxxviii. p. 278.
[5] *Mém. Acad. Sci. St. Petersb.*, vol. xxvi. No. 7, pl. ii. fig. 9.

Colour.—Violet.

Habitat.—Station 188, September 10, 1874, lat. 9° 59′ S., long. 139° 42′ E.; depth 28 fathoms; green mud.

Family SPONGELIDÆ, F. E. Schulze, 1878.

Dysideidæ, Gray, 1867, and Marshall, 1881.
Arenosa, Carter, 1875.
Spongiadæ (*e. p.*), and *Hircinidæ* (*e. p.*), Hyatt, 1877.

Keratosa with flagellated chambers of more or less regularly roundish outlines, communicating by means of numerous pores in their walls with inhalent, by means of one wide mouth with exhalent, cavities; ground-mass transparent, without granules. Axis of fibres thin; fibres cored in most cases with foreign enclosures.

Spongelia, Nardo.

Dysidea, Johnston.
Spongelia, *Dysidea*, and *Psammascus*, Marshall.

Spongelidæ with large flagellated chambers; outer surface provided with conuli.

Spongelia spinifera, F. E. Schulze.

Spongelia spinifera, F. E. Schulze, Zeitschr. f. wiss. Zool., Bd. xxxii. p. 152, 1878.

This species, established by F. E. Schulze in the year 1878 for some forms from the Adriatic, is characterised by him as follows:—"The conuli, 5 to 8 mm. high, situated at equal distances from one another, run out in simple thorn-like processes; among the simple ramified primary fibres no communicating secondary fibres are to be found, so that accordingly the skeleton forms no network." The chief character, since the size of the conuli is in other representatives of the genus variable, is thus the dendroid ramification of the skeletal fibres which do not anastomose with one another. In this chief character both the Challenger specimens, which I have determined as *Spongelia spinifera*, agree; but while one, differing from the Adriatic forms as regards its lower conuli, agrees with them in its mode of growth, being found like them in the form of a crust, the second specimen differs from them even in this latter point, presenting a laterally compressed leaf 25 mm. high, 20 mm. broad, and 5 mm. thick in the middle, and rather thinner near the border. The conuli of *both* the specimens do not exceed 4 mm. in height, and in accordance with this peculiarity I propose to establish for them an independent variety—*parviconulata*, while the designation *magniconulata* might be used for forms like the Adriatic *Spongelia spinifera*. No peculiarities of consequence were noticed with regard to the structure of

the soft parts; the oscula, scanty in the incrusting specimen, proved to be thoroughly deficient in that of leaf-like shape; one of the specimens proved to be sterile; the other was provided with numerous sperm-balls. The habitat of *Spongelia spinifera*, hitherto found only in the Adriatic, is now extended to the east coast of Australia.

Colour.—Pale greyish and dirty yellowish.

Habitat.—Off Port Jackson, depth 7 fathoms.

Spongelia pallescens, O. Schmidt (Pl. III. fig. 1).

This species, whose detailed definition we owe also to F. E. Schulze,[1] has been divided by him into two subspecies, and each subspecies in its turn split into two varieties. The numerous Challenger specimens of *Spongelia pallescens* are all to be determined as subspecies *fragilis* var. *ramosa*, but I must add that while the diagnosis of this variety as given by F. E. Schulze is thoroughly applicable to the Challenger specimens, the meshes of their skeletons proved to be of rather larger diameter than those of any of the Spongelidæ with anastomosing fibres examined by F. E. Schulze, and whose skeletons, through his kindness, have all been placed at my disposal. Whether this difference is of individual or varietal or even specific value, I am unable to decide, and therefore limit myself to merely mentioning it.

Colour.—Pale yellow and lilac.

Habitat.—Bahia, shallow-water.

Spongelia horrida, Selenka (Pl. III. fig. 2).

Spongelia horrida, Selenka, Zeitschr. f. wiss. Zool., Bd. xvii. p. 566, pl. xxxv. figs. 1-4, 1867.

This species, placed by Selenka in the genus *Spongelia*, has also been adopted by F. E. Schulze,[2] but apparently only on account of its form and the properties of the skeleton. I am pleased to be able to sanction this proceeding, as the external shape and structure of the skeleton of the Challenger specimens agree closely with those of the forms described by Selenka, and their internal organisation is that of a typical *Spongelia*. The identification of the forms in question is, on the other hand, confirmed by the fact that both the Challenger and Selenka's specimens were from Australia.

The Challenger Collection possesses three specimens of *Spongelia horrida;* two are in the form of crusts 12 to 18 mm. high, the third being of a more massive appearance. But all three specimens are equally constant to the main character of the species, the meshes of their skeleton being far larger than in any other *Spongelia*, as may be seen on Pl. III. fig. 2. The foreign enclosures of the fibres proved to be chiefly

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxxii. p. 154, 1879.

[2] *Ibid.*, Bd. xxxii. p. 122.

fragments of spicules and small sand-grains; the capsules with cellular elements found within the fibres by Selenka (*loc. cit.*, p. 566, pl. xxxv. figs. 3–4) were not to be seen.

Colour.—Pale yellowish.

Habitat.—Station 186, September 8, 1874, lat. 10° 30′ S., long. 142° 18′ E.; depth 8 fathoms; coral mud.

Psammoclema, Marshall.

Spongelidæ with small flagellated chambers; external surface smooth.

Psammoclema ramosum, Marshall (Pl. III. fig. 8; Pl. IV. fig. 1).

Psammoclema ramosum, Marshall, Zeitschr. f. wiss. Zool., Bd. xxxv. pl. vii. fig. 12, 1880.

It is sufficient to compare the drawing of this form given by Marshall with that given by me on Pl. IV. fig. 1, in order to become persuaded of the fact that both the Challenger and Dr. Marshall's specimens belong to the same species. There are, however, in the description which Dr. Marshall gives of his specimens, two points at variance with my observations, but I am inclined to explain one of them by a mistake on the part of Dr. Marshall, and the other by a real difference in organisation but of no essential nature.

It has been stated by Marshall that the skeleton of his *Psammoclema ramosum* is tree-like, the main fibres sending lateral branches which ramify in their turn but form no anastomoses. I can state the same with respect to the *upper ends* of the branches of the animal, but so far as other parts of its body are concerned, I discerned the anastomoses clearly (Pl. III. fig. 8). Again, Dr. Marshall believes the canal system of this species to be of special interest. He says: "Die Mundöffnungen befinden sich alle auf einer Seite, wie bei manchen Formen von *Halichondria oculata*, Grant, und bei *Veluspa polymorpha* var. *digitata*, Miclucho. Es scheint dies dafür zu sprechen, dass der Schwamm nicht aufrecht wächst, sondern wie viele Pflanzen im Meere, horizontal. Ein aufrechtes Wachsthum dürfte wohl auch schon bei der Schwere des Schwammes seiner geringen Festigkeit und Widerstandsfähigkeit gegenüber unmöglich sein."[1] Indeed, on some branches of the Challenger specimen the oscula were all found on the same side, but on others they were scattered everywhere, and having examined the external surface of the specimen, I found all its parts equally smooth and clean. I must therefore differ from Dr. Marshall with regard to his conclusion as to the kind of growth of the animal. I think it grows vertically, and am inclined to believe that the peculiarity in the disposition of the oscula on Dr. Marshall's specimens is characteristic only of the individual. For a more detailed description of the animal, I refer the reader to the paper of Dr. Marshall above mentioned, and will only add that its flagellated chambers agree closely as regards form and size with those of my *Psammoclema vosmaeri* (Pl. III. fig. 6), and that, on the

[1] *Loc. cit.*, p. 112.

whole, its internal organisation does not differ from that of the representatives of the genus *Spongelia*, except in the size of the flagellated chambers. What Dr. Marshall means by the words, "Das Gastrovascular-System ist hier nach dem astförmigen Typus angeordnet" (*loc. cit.*, p. 113), is of course to be regarded as an echo of corresponding erroneous statements of Prof. Haeckel. For any fine histological examinations the Challenger specimen proved to be insufficiently preserved. The Alga found by Marshall in all the specimens he had for examination was found to be characteristic also of the single specimen collected by the Challenger.

Colour.—Grey, skeletal fibres white.

Habitat.—Station 162, April 2, 1874, off East Moncœur Island, Bass Strait; depth 38 fathoms; sand and shells. Dr. Marshall's specimens were also obtained from Bass Strait.

Psammoclema vosmaeri, n. sp. (Pl. III. figs. 5 and 6).

This interesting species has been found in one colonial specimen, which is depicted of natural size on Pl. III. fig. 5. Some individuals of the colony are mouthless, the oscula of others are very small, and others again present cylindrical tubes, the diameter of the oscula being thus the same as that of their body in its different parts.

The surfaces of the sponge though entirely devoid of any conuli, are still rather uneven and rough, but whether this is due to the state of preservation or is characteristic of the species I cannot judge. The skeleton, when seen from the outer surface, admits of no distinction into primary and secondary fibres, the network of the fibres being very compact, *i.e.*, the meshes of a very small diameter, and it is only on the inner surface that the vertically directed primary fibres, 0·16 mm. thick on an average, are easily distinguishable; most of the fibres, and particularly the larger ones, are charged with foreign enclosures to such a degree that the enveloping horny substance is very thin and the surface of such fibres very rough. When dried the skeleton becomes hard and of a greyish colour. The type of the canal system and the histological structure do not differ from those, for example, of *Spongelia pallescens*, except that the flagellated chambers are of smaller dimensions and comparatively more constant in their roundish form, and that the internal cavity in some individuals is very large. Through the pores of the outer surface the water reaches the system of inhalent canals, flagellated chambers and exhalent lacunæ opening by comparatively small holes into the internal cavity.

From all other representatives of the genus hitherto known this species can be readily distinguished both by its external shape, which is more like that of a calcareous than a horny sponge, and by the compact network of its skeletal fibres, also perhaps by the tendency to form colonies.

I dedicate the species to Dr. G. C. J. Vosmaer of Naples.

Colour.—Pale greyish-yellow; skeletal fibres dirty greyish.

Habitat.—Station 186, September 8, 1874, lat. 10° 30′ S., long. 142° 18′ E.; depth 8 fathoms; coral mud.

Psammoclema foliaceum, n. sp. (Pl. III. fig. 7).

Like *Psammoclema ramosum*, the species in question was brought home in fragments, all, however, in both cases belonging to one specimen. When put together, the fragments of the Challenger *Psammoclema foliaceum* form a whole which may be compared with my drawing of *Carteriospongia radiata*, but which is approximately four times as large, with walls from two to four times as thick in different parts of the body, and with surfaces of a rather shagreen-like appearance and not distinguished by the system of longitudinal ribs. The resemblance in the form; the fact that, as regards the anatomical structure of the canal system, *Psammoclema* is closely allied to *Carteriospongia*; and again, that most of the representatives of this latter genus also possess fibres full of foreign enclosures; all render the form I am now describing extremely interesting from a phylogenetic point of view. This has led me to make greater endeavours to find out its histological structure in the hope of discovering in it the anastomosing "Stränge" of F. E. Schulze, the function of which is of course doubtful, but which are so very characteristic of *Carteriospongia* and of all the Spongidæ generally. The specimen proved, however, to be so very badly preserved that I had to be content with making out its anatomical organisation, and thus assigning to it a definite systematic position.

A portion of its skeleton is represented on Pl. III. fig. 7; like that of *Psammoclema vosmaeri*, it is of a dirty-greyish colour, due to the abundance of foreign enclosures in its fibres, but the meshes are larger, and when seen against the light the primary fibres become very clearly visible. I characterise the species exceptionally by its external shape, but of course I am uncertain whether I am right in this proceeding. Later investigations will decide the question.

Colour.—Black; skeleton grey.

Habitat.—Station 162, April 2, 1874, off East Moncœur Island, Bass Strait; depth 38 fathoms; sand and shells.

Psammopemma, Marshall.

Spongelidæ without any differentiated skeletal fibres, the supporting skeleton being represented by foreign enclosures lying separately in the parenchyma, and the secretion of the horny substance having been reduced to the formation of only a thin envelope around the enclosed foreign bodies.

Psammopemma densum, Marshall (Pl. III. figs. 3, 4).

Psammopemma densum, Marshall, Zeitschr. f. wiss. Zool., Bd. xxxv. p. 116, 1880.

When characterising this species, Dr. Marshall did not feel quite certain whether he was really describing a sponge and not a worm-tube or something of that kind. Of course, I have scarcely the right to express an opinion on this delicate question, still I believe it to be a sponge; at any rate I can state with the greatest certainty that such sponges, *i.e.*, sponges without any differentiated skeletal fibres but still secreting horny substance, do really exist. Sanctioning thus the establishment of the genus *Psammopemma*, I adopt also Dr. Marshall's species *Psammopemma densum*, since its specific designation is very characteristic of two specimens in the Challenger Collection, and especially of that from Port Jackson.

This last specimen is represented in Pl. III. fig. 3, and it will be obvious from this drawing that the original is probably not the whole animal but only a fragment of it. Now even if this fragment give no precise idea as to the shape of the whole animal, it must still be assumed that this latter was of a plate-like compressed form, supposing the fragment in question was not merely an outgrowth; while the external shape of the second Challenger specimen, represented also only by a fragment, must have been either crust-like or massive, the plane of the fracture being parallel to its outer surface.

So far as this latter is concerned, it is in both specimens uneven and throughout its whole extent rough, owing to prominent sand-grains, often 1 mm. in diameter. In the Australian specimen, at one point on its surface, I found a shallow depression, which I am inclined to regard as the osculum; but I refrained from trying to prove it by immediate dissection lest I should destroy the specimen in vain, the sponge presenting such a compact aggregation of sand-grains that only very thick sections could have been obtained from it by the microtome. Besides, the question is of little consequence.

In contrast to the specimens which Dr. Marshall had for examination, both the Challenger specimens proved to be free from any parasitic inhabitants, as well as from any skeletal fibres, either foreign or produced by the sponge itself. Nor can I say that the foreign enclosures are held together by protoplasm as stated in Marshall's definition of the genus (*loc. cit.*, p. 113); each of them, though surrounded by a thin horny envelope, having been found lying separately in the parenchyma. That the envelope just mentioned is of a horny nature I judge from the fact that it does not differ from the envelopes to be found around foreign enclosures in other Spongelidæ, lying free in the "sarcode," these latter in their turn not differing from the envelope of true skeletal fibres overcharged with foreign bodies. Contrarily to Marshall (*loc. cit.*, p. 114), I find this envelope to be

quite devoid of any enclosed corpuscles. As to the foreign enclosures themselves, they are represented in both the Challenger specimens almost exclusively by sand-grains, some of Dr. Marshall's specimens having proved to be also very rich in them, while others, on the contrary, were poor in sand and rich in fragments of mussel-shells. I agree entirely, however, with Dr. Marshall as to the impossibility of paying any systematic attention to such differences. Of course the faculty has been ascribed to sponges of choosing from the available foreign bodies those which they need. Haeckel adopts it with respect to his *Physemaria;*[1] and Carter, though on a different occasion,[2] speaks also of "that developmental intelligent power whose existence in every organised product is only known to us by its manifestations." However, the contrary opinion, held by F. E. Schulze and Marshall, is supported by more valid arguments, and there is absolutely no necessity for introducing into our scientific calculations a new thoroughly unknown factor, while the phenomenon admits of a very simple and plausible mechanical explanation.

So far now as the anatomy of the form in question is concerned, Marshall believes the *Psammopemmata* to be of very low organisation, and if I understand him aright, he sees it in their lipostomy and lipogastry. These two peculiarities, provided that the lipostomy be really characteristic of the genus, are, however, of very subordinate significance; a lipostomic and lipogastric Leuconid is yet more highly organised than a Sycon provided with the broadest central cavity and with an osculum fringed with the most elegant spicules,—such questions, without knowledge of the structure of the canal system, not being at all capable of solution. That of the *Psammopemmata* agrees in its features closely with that, for instance, of *Spongelia pallescens*, as described by F. E. Schulze. The flagellated chambers are large, of more or less regularly roundish outlines, and devoid of any special cameral canaliculi; the ground-mass surrounding them is transparent and without granules (Pl. III. fig. 4). There is also a close resemblance to the representatives of *Spongelia* in the histological properties, the only difference being that such aggregations of fusiform cells as Schulze[3] describes for *Spongelia avara* are not to be found in the two Challenger specimens of *Psammopemma*. In this statement I differ from Marshall, who lays stress on their constant occurrence in (under ?) the covering dermis. I find these fusiform cells scattered everywhere and also under the dermal membrane, but in most cases lying isolated, and never in such mutually parallel disposition as in Marshall's illustration (*loc. cit.*, pl. viii. fig. 10). Nor can I agree with him as to this dermal membrane being homogeneous (*loc. cit.*, p. 113). I found it to contain nuclei disposed at approximately equal distances from one another, and on the ground of numerous analogies I am inclined to regard it as a common pavement-epithelial layer, the boundaries of its separate cells having disappeared owing to the preservation in alcohol.

[1] Biolog. Studien, Heft. ii. p. 213.

[2] I refer to his discussion of the process of the horny skeletal fibres taking in and enclosing the foreign bodies, *Ann. and Mag. Nat. Hist.*, ser 5, vol. viii. p. 113.

[3] *Zeitschr. f. wiss. Zool.*, Bd. xxxii. p. 136.

The reader sees that there are many points in which I disagree with Dr. Marshall. Most of the contradictions are, however, insignificant, and the remaining ones, I feel certain, are to be explained by the fact that Dr. Marshall's specimens were either in a dried state or very badly preserved. At any rate, I see no reason against adopting both the genus and the species.

Colour.—Sandstone-yellowish.

Habitat.—Station 49, May 20, 1873, lat.. 43° 3′ N., long. 63° 39′ W.; depth 85 fathoms; gravel and stones. Off Port Jackson, 7 fathoms.

Psammopemma porosum, n. sp.

In his paper on systematic rules Strickland suggests that generic and specific designations should be given which allude to the main generic or specific character of the given form;—very good counsel indeed, yet it occurs but too often that whilst following it the classifier creates very unfortunate systematic designations, and so far as the species I am going to describe is concerned, I feel by no means certain that—just as we find *Ancorinæ* without any anchor-like spicules—specimens of *Psammopemma porosum* will be found of no less density than that of the Challenger specimen of *Psammopemma densum* from Port Jackson. Still I do not take refuge in naming the species in question according to its second and undoubtedly more important character, for this latter character may prove to be of a subgeneric consequence. The species is represented in the collection by numerous small fragments, which, formless as they are, show distinctly that the external shape of the specimen—or, perhaps, specimens—dredged by the Challenger must have been of a rather stout, massive appearance. Apart from this character as well as from the porosity, which latter peculiarity may stand in connection with the massive shape of the animal, the fragments in question recall vividly as regards their form the Challenger specimens of *Psammopemma densum*, and especially that from Nova Scotia. Their colour is a dirty sandstone greyish, and the presence in the parenchyma of foreign enclosures (chiefly sand-grains, and, only in the upper skin, fragments of spicules) is well marked in the roughness of the surfaces.

As I remarked before, one of the characters of the species may be its porosity. I have but to add that this peculiarity must be really regarded as characteristic at least of the specimen, for there is no reason to suggest that the parenchymal cavities in question are due to worms as in the specimens of *Psammopemma densum* examined by Dr. Marshall. Except a Hydroid (*Aglæophenia*, sp. ?) rooting in one of the fragments and the doubtful round bodies to which I shall refer later, I miss any parasitic inhabitants entirely.

The second peculiarity characterising this form is the minuteness of its flagellated cells, which are smaller than in any horny sponge hitherto described. It is only in some Corticatæ (*Stelletta grubei, Geodia gigas, Ancorina aaptos, Tethya lyncurium*) that I

have seen these elements so strikingly minute. This peculiarity renders the sections of them readily distinguishable under the microscope from those of any other Porifera, and my first idea when examining the preparations of *Psammopemma porosum* was that this form might represent an offspring of the family above mentioned. Yet an attentive examination showed that the species has even more right to be referred to the Keratosa than *Psammopemma densum;* for while in this latter form the horny substance enveloping the foreign enclosures has been found in the form of an extremely thin layer, so that its presence beyond doubt could only be proved in most instances after treatment with hydro-fluoric acid, here in *Psammopemma porosum* it proved to be far more fully developed, and occasionally with very conspicuous outgrowths.

On p. 17 I have shown that on the whole, as the canal-system reaches a higher degree of development, the size of the flagellated chambers gradually diminishes. Of course the flagellated chambers of *Psammoclema vosmaeri* are not larger than those, for instance, of *Euspongia officinalis*, and yet they are devoid of special cameral canaliculi, but every rule has its exceptions. *On the whole*, the above dependence is still to be observed, and it is not without interest that as flagellated chambers become smaller and smaller the flagellated cells in their turn grow gradually more and more minute. The flagellated cells of *Aplysilla sulphurea* are larger than those of *Spongelia elegans*, which again are larger than the flagellated cells of *Cacospongia scalaris* or *Aplysina aërophoba*. But, as in the preceding case, exceptions are not wanting here also; *Ianthella flabelliformis* does not deviate in the structure of its soft parts from the type characterising *Aplysilla sulphurea*, and yet possesses flagellated cells of far smaller dimensions than those of the form just mentioned. Again in *Euplectella aspergillum*, in spite of its large, radial tube-like flagellated chambers, these cells are very minute. *Psammopemma porosum* presents, in this respect, the most interesting exception. As stated before, its flagellated cells are very small; while for instance in *Cacospongia scalaris* the diameter of their transverse section is 0·0025 mm., on an average in *Psammopemma porosum* it does not exceed 0·001 mm.; and yet its flagellated chambers, although smaller than those of *Psammopemma densum*, are rather larger than those of *Cacospongia scalaris* or *Euspongia officinalis*. The explanation of this curious deviation must be of course left to later investigations, but there can be scarcely any doubt that, if not even of a subgeneric importance, at any rate it necessitates the establishment of a new species, although on the whole the internal organisation of *Psammopemma porosum* agrees closely with that of *Psammopemma densum*. As a probably accidental peculiarity I can notify the presence in the parenchyma of numerous round bodies, with an average diameter of 0·012 mm., which at first sight recall vividly the spermospores of Calcarea or Aplysinidæ (p. 72). Under high microscopic power these bodies proved however to be devoid of any covering cell, and though their contents are apparently cellular elements and their size approximately the same as that of the spermospores of

Verongia hirsuta (?) or *Verongia tenuissima* (?), I yet incline to the belief that they stand in no connexion with the sponge organism.

Colour.—Sandstone yellowish-grey.

Habitat.—Bahia, shallow water.

In addition to the well-marked Spongelidæ just described, there are in the Challenger collection three specimens probably belonging also to the family in question, but so very badly preserved that there are no soft parts on their skeleton. I believe it advisable to abstain entirely from their detailed description. I think that an undescribed form is of greater profit to science than a form described insufficiently for subsequent recognition. I *believe* the sponges just mentioned belong to the Spongelidæ, but the question whether a sponge belongs to this or that family in the Keratosa cannot be decided from the properties of the skeleton alone. Again I cannot describe them only as species; the external shape plays a great part in the specific description, but the exterior of the sponge is influenced by the properties of its soft parts, and these as mentioned before are entirely absent. An entire abstinence from any description seems to me therefore to be the best plan.

Family Spongidæ.

Spongiadæ and *Hirciniadæ*, Gray, 1867.
Bibulida and *Hircinida* (*e.p.*), Carter, 1875.
Spongiadæ (*e.p.*), *Hirciniadæ* (*e.p.*), and *Phyllospongiadæ*, Hyatt, 1877.
Spongidæ and *Hircinidæ*, F. E. Schulze, 1879.

Keratosa with small hemispherical flagellated chambers, communicating by means of numerous pores with inhalent, by means of special canals with exhalent, cavities. Axis of fibres thin; ground-mass in the neighbourhood of the flagellated chambers granulated.

Coscinoderma, Carter.

Spongidæ with skeletal fibres admitting of no distinction into primary and secondary ones.

Coscinoderma confragosum, n. sp.

"Battledore-shaped, covered with a white continuous cribriform incrustation; surface even, with fibres almost uniformly alike in size and colour, viz., very small and fine, very long, scantily branched, curled up together in little whorls, of a deep sponge colour." In these words Mr. Carter[1] characterises his genus *Coscinoderma*, and together with it his species *lanuginosum*. The species I am about to describe agrees very well with that description, but presents the following differences. When bisected longitudinally the

[1] *Ann. and Mag. Nat. Hist.*, ser. 5., vol. xii. p. 309, 1883.

form of the section may be compared with a battledore, though the stem must be called very thick, and besides ends with a basal extension; but only as regards the plane of the section, the whole not being compressed, but of a massive form and of rather roundish outline. The colour of the incrustation is not white but pale greyish; and the colour of the skeletal fibres is only straw-yellow. Again, I cannot call the outer surface of my specimen unconditionally even; at anyrate the surface of the skeleton devoid of soft parts is denticulated; these denticulations are not, however, the terminal points of single fibres, but whole networks in the form of sharp-pointed projections. All these peculiarities together, and particularly the formation of sharp-pointed projections on

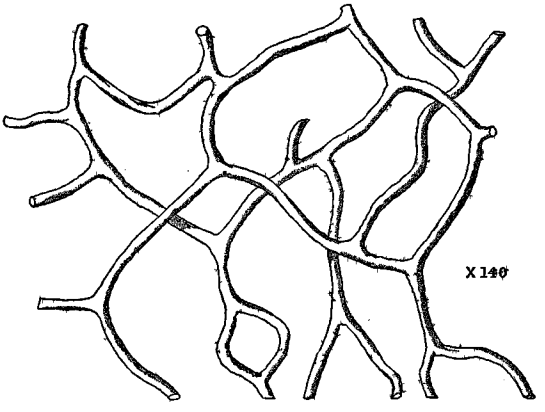


FIG. 1.—Skeletal fibres of *Coscinoderma confragosum*.

the surface of the skeleton, quite absent in *Coscinoderma lanuginosum*, Carter, necessitate the establishment of a new species. In the accompanying diagram a portion of the skeleton is represented in order to show the manner in which the fibres interlace with one another. The fibres themselves are entirely devoid of any foreign enclosures, and their average thickness is 0·015 mm. The species is represented in the collection by a single specimen, dredged by H.M.S. "Porcupine."

Colour.—Outer surface greyish, parenchyma pale grey-yellowish, skeletal fibres straw-yellow.

Habitat.—H.M.S. "Porcupine," Station 13, 1870, off the coast of Portugal; depth 220 fathoms.

Coscinoderma dentieulatum, n. sp. (Pl. VI. fig. 4).

This species, also represented by a single specimen, agrees with *Coscinoderma confragosum* as regards the formation of sharp-pointed projections of the skeleton, though

here they are visible also when covered with soft parts, so that the outer surface of the sponge is distinguished throughout by small conuli 0·2 to 0·33 mm. high, the average distance between them being 1 mm.; but it differs both from *Coscinoderma lanuginosum* and *Coscinoderma confragosum* with respect to the character of its surface, which has no special superficial incrustation, the skin not differing from that of *Euspongia* or *Cacospongia*, and the manner in which the fibres form meshes. As in most other Spongidæ, the meshes are here polygonal, although still formed by fibres all of the same size—on an average 0·042 mm., *i.e.*, almost three times as thick as those of *Coscinoderma confragosum*—a new character distinguishing this species both from *Coscinoderma lanuginosum* and *Coscinoderma confragosum*. The average size of the meshes is 0·25 mm. In external shape the specimen representing this new species in the Challenger collection is in the form of a crust, but with local thickenings 10 mm. in height. In contrast to the Challenger specimen of *Coscinoderma confragosum*, which shows a very well developed oseulum, no oscula can be discerned on the surface of this specimen.

Colour.—Soft parts pale greyish, skeletal fibres brownish-yellow.

Habitat.—On the reefs Honoruru, Sandwich Islands; depth 40 fathoms.

Coscinoderma altum, n. sp. (Pl. V. figs. 4–6).

This species is a good species also, provided of course that the genus *Coscinoderma* be good. The meshes of the skeleton, as in the species just described, are of polygonal outline, but on an average twice as large, the fibres themselves being one and a half times as thick. Unlike all other representatives of the genus hitherto known, the fibres are abundantly charged with foreign enclosures, so that they appear of a rather dirty-white colour. Again, the external appearance of the sponge itself is novel, and is perhaps not devoid of systematic importance. While in the two preceding species we have had to deal with forms either incrusting or massive, *Coscinoderma altum* is found in the form of a long cylindrical stalk with rounded upper end 230 mm. high and about 18 mm. broad, with denticulated outer surface, the prominences 0·75 mm. high and 2 mm. apart being however rather blunt, and the skin itself presents the same appearance as that of *Aplysina cærophoba* as drawn by F. E. Schulze.[1] The specimen contained numerous Morulæ, and I make use of this opportunity in order to turn attention to a peculiarity which, in a still higher degree, I have very often observed in *Cacospongia* and *Euspongia*, as mentioned in my paper "Ueber die Spermatogenese bei *Sycandra raphanus*," but which, as far as I am aware, is hitherto undescribed. I mean the extraordinary growth of the endothelial cells surrounding the growing embryos. They do not differ in size from other parenchyma-cells when young, but as they grow they do not become like the pavement-cells, but increase both in area and volume. Again, when surrounding a Morula

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxx. pl. xxi. fig. 1, 1878.

these cells are readily distinguishable from all other cellular elements not only by their extraordinary size but also by their containing numerous, and comparatively very large, granules. That a generative product when it—contrary, *e.g.*, to the spermospores of Calcarea—increases during maturation, must receive nutritious material from the surrounding parts of the parent body is indeed obvious, but in the Porifera this may be done in two ways, either by the endothelial cells playing an intermediate part, or, by means of a certain modification, becoming so to speak staples for the material to be consumed by the growing product. The first is the case as regards the sperm-balls, their endothelial cells in all stages of development representing typical pavement-cells, and with further growth gradually becoming rather flatter. Since a sperm-ball, for instance, of *Aplysilla sulphurea* when quite mature is many times larger than the cell from which it derived its origin, it must be assumed that its increase is due not only to the nutritious material within the primitive cell itself, but also to the material absorbed from the surrounding elements. Now the surrounding elements, viz., the endothelial cells, are neither voluminous nor rich in nutritious particles; thus the only possible conclusion is that these endothelial cells having received nutritious material from other cellular elements do not retain it but give it up instantly to the generative product. On the contrary, the endothelial cells surrounding a developing embryo of, *e.g.*, a *Cacospongia scalaris* retain the nutritious particles, and it is in this property that we have also a natural explanation of the striking aggregation of mesodermic cells in the neighbourhood of a developing embryo, as observed and described by F. E. Schulze.[1]

Colour.—Outer surface brownish, parenchyma and skeletal fibres pale greyish.

Habitat.—Station 135A, October 16, 1873, off Tristan da Cunha; depth, 75 fathoms; hard ground, shells, and gravel.

Euspongia, Bronn.

Spongidæ with fine skeletal fibres forming a compact network, the meshes being very small; primary and secondary fibres readily distinguishable.

Euspongia officinalis (Linné), var. *lobosa*, n. var. (Pl. VI. fig. 1).

The single specimen on which this variety is founded recalls by its external shape the drawing which F. E. Schulze[2] gives of *Euspongia officinalis* var. *tubulosa*, with the distinction that its basal part is not plate-like as in the latter, but massive. As in most *Euspongiæ* the outer surface is denticulated owing to the prominent primary fibres, but here the conuli are very low, their height not exceeding 0·3 mm. A portion of the skeleton is represented on Pl. VI. fig. 1; it is bush-like, and it must be noticed that while

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxxiii. pl. iii. fig. 1, 1880. [2] *Ibid.*, Bd. xxxii. pl. xxxiv. fig. 8, 1879.

in other *Euspongiæ* the primary fibres run usually more or less parallel to one another, here they show a very pronounced tendency to ramify; the spaces between them and their secondary, but still vertically directed, branches being filled with an irregular network of fibres originating also from the primary ones, but in a more or less horizontal direction. The average basal diameter of the primary fibres is 0·1 mm., that of the tertiary only 0·03 mm. The latter, in contrast to the primary fibres, are in most cases quite free from foreign enclosures. This variety is a connecting link between *Euspongia officinalis* and *Cacospongia mollior*, and may be classed in the species last mentioned with the same right as in *Euspongia officinalis*.

Colour.—Outer surface pale greyish, parenchyma colourless, fibres straw-yellowish.

Habitat.—Bahia, shallow water.

Hippospongia, F. E. Schulze.

Spongidæ with fine skeletal fibres and small meshes, the fibres admitting of no distinction into primary and secondary ones; distinguished by a system of canals permeating the body in all possible directions.

Hippospongia anomala, n. sp. (Pl. VII.; Pl. VI. fig. 2).

This species is represented in the Challenger Collection by a single but very large specimen 350 mm. broad, 200 mm. high, and 40 mm. thick, drawn of the natural size, but in a bent position on Pl. VII. For its characters, common to the whole genus, I refer to the diagnosis in the foregoing paragraph. The character distinguishing it from other species of the genus is a property which renders its grouping in the genus *Hippospongia* rather disputable. I mean the presence of quite distinct primary fibres directed obviously towards the outer surface, on an average four times as thick as the others, and absent only in the skeleton supporting the thin membranes covering the lacunæ immediately under the outer surface. It must be said that the terminal skeletal processes of a *Hippospongia equina*, when seen with the naked eye, show within them certain streaks perpendicular to the outer surface; but these streaks and the fibres in question of my *Hippospongia anomala* are quite different things, the last-mentioned being really nothing but single fibres thicker than the others, the first-mentioned being composed of many fibres and differentiated from the surrounding parts of the skeleton by the fact that the network formed by the fibres is here more compact than elsewhere. The appearance is therefore only an optical illusion; at any rate the property in question distinguishes my species readily from all others of the genus, but does not, however, decide the question whether it really belongs to the genus *Hippospongia*. Still I am of this opinion. As regards the rigidity of the skeleton this specimen is, indeed, allied to *Cacospongia mollior*; but apart from distinctions concerning the presence of the system of canals

permeating its body, the external shape of the animal and particularly its shagreen-like surface, its skeleton (more compact than, but not nearly so hard as, that of *Cacospongia mollior*) recalls that of a *Euspongia* rather than that of a *Cacospongia*.

If now this species, as regards the property of its skeleton, were a typical *Euspongia*, the question as to its systematic place would be still more difficult; one classifier might place it in the *Euspongiæ*, another, and on grounds of equal validity, among the *Hippospongiæ*. Now the species in question is neither a *Euspongia* nor a *Cacospongia*, nor a typical *Hippospongia*; but since one of the main characters of *Hippospongia* is very characteristic of this specimen, the most logical proceeding will be, I think, to group it in this latter genus. For my own part I do not doubt that the species in question, be it referred to *Hippospongia* or *Euspongia*, will still remain a good species, and I shall be quite content if my description prove sufficient for future recognition. In order to render it more complete I add the following details. The average diameter of the primary fibres reaches 0·12 mm., that of the secondary fibres being on an average only 0·028 mm.; the latter are nearly all quite free from any foreign enclosures; the first-mentioned, however, are so full of them that their surface is of a rather angular character, owing to the fact that these foreign bodies lie not only in the central part of the fibres but also in their peripheral portions, projecting outwards and thus rendering the surface of the fibres uneven. It is in this form that I have found, hand in hand with normal flagellated chambers, chambers devoid of any special cameral canaliculis, although in other details its internal organisation presents no deviations from that, for instance, of *Euspongia officinalis*. The specimen proved to be sterile.

Colour.—Soft parts and outer surface pale yellowish-white, skeleton straw-yellow.

Habitat.—Station 186, September 8, 1874, lat. 10° 30′ S., long. 142° 18′ E., depth 8 fathoms, coral mud.

Hippospongia mauritiana (Pl. VI. fig. 3).

Spongia lapidescens, Duchassaing de Fonbressin et Michelotti; subspecies *mauritiana*, Hyatt, Revision, &c., vol. ii. p. 527.

There can be scarcely any doubt that the three specimens of the collection now under consideration are to be referred to Hyatt's *Spongia lapidescens*, subspecies *mauritiana*. His description is very good and detailed, and the form itself, owing to the density of its skeleton, admits of a very clear definition. But what appears to me very strange is that Hyatt still finds it possible to distinguish in its skeleton primary and secondary fibres. I find them all approximately of the same size; of course the bundles of parallel fibres projecting from the outer surface are directed vertically, but seeing that they are not united one with another by smaller horizontal fibres, and that they do not differ in thickness from other fibres of the skeleton, I see absolutely no grounds for regarding

them as primary; and it is owing to this character, as well as to the body being permeated by a regular system of internal canals, that I must[1] place the form in question as a new species in the genus *Hippospongia*, F. E. Schulze.

Colour.—Soft parts yellowish-pale, skeletal fibres dark yellow.

Habitat.—Off Api, New Hebrides, 18th August, 1874; depth 60 to 70 fathoms.

Cacospongia, Oscar Schmidt.

Spongidæ with readily distinguishable primary and secondary skeletal fibres of comparatively thick diameter and forming comparatively large meshes.

Cacospongia levis, n. sp. (Pl. V. figs. 1–3).

The external surface of the single Challenger specimen is quite smooth except in some spots where is is rather roughened by the ascending primary fibres. It is in this property that, bearing in mind the conjectural affinities of the species, I am inclined to see its most important systematic character. The species seems to be closely allied to *Cacospongia mollior*, but as we learn from F. E. Schulze (compare his drawing in the memoir on the Spongidæ), the outer surface of the latter is denticulated throughout. Again, the meshes of *Cacospongia levis* are rather smaller than those of *Cacospongia mollior*, and its primary fibres are 0·08 mm., the secondary ones only 0·04 mm. thick, the corresponding fibres in *Cacospongia mollior* being on an average 0·15 mm. and 0·05 mm. in diameter. Approaching as regards these latter characters to my *Hippospongia anomala*, the species in question differs both from it and from *Euspongia officinalis* var. *lobosa* in a sharply pronounced rigidity of its skeleton. Just as in *Hippospongia anomala*, the body of my *Cacospongia levis* proved also to be perforated by numerous canals, but neither do these canals show, on the whole, any regular arrangement, being quite analogous to those of *Cacospongia cavernosa*, nor is any membrane to be found above their terminal points, so that there can be no doubt as to the systematic position of this sponge. The primary fibres though not prominent may still be readily distinguished (Pl. V. fig. 2). They proved to be cored with foreign bodies, chiefly fragments of spicules lying, however, only in the central part of the fibre; in contrast to this, the secondary fibres are quite devoid of any enclosures. In the soft parts of the specimen in question I found some formations which though lying free in the parenchyma, *i.e.*, not surrounded by a special endothelial layer, nevertheless presented a great resemblance to sperm-balls. A more careful examination and the application of high magnifying powers showed, however, that these formations are scarcely identical with sperm-balls. Their contents consist of numerous oval bodies in which no nucleus could be distinguished, but quite homogeneous throughout

[1] Comp. p. 84.

their whole extent, and, in spite of my endeavours to discover any initial or further stages in their development, I find these oval bodies enclosed, though differing in size but always with precisely the same external appearance. I believe they belong to some low plants.

Colour.—Outer surface black, parenchyma dirty yellowish-grey, skeletal fibres brownish-yellow.

Habitat.—Off Barra Grande, September 10, 1873; depth 400 fathoms, red mud.

Cacospongia amorpha, n. sp. (Pl. VI. fig. 5).

The properties of the skeleton of this species recall those of *Euspongia officinalis*, var. *lobosa*, as regards the tendency of the primary fibres to ramify, but the fibres, both primary and secondary, are comparatively far larger, as are also the meshes formed by them; one might illustrate the difference between these two forms by comparing them to a bush and a tree.

The species is represented by two specimens, one of a massive stout appearance, the other 100 mm. high by about 20 mm. thick, of roundish outline in the upper part, and flatly compressed near the rather extended bases. The outer surface is denticulated by prominent primary fibres forming conuli of 1 mm. on an average, and 3 to 5 mm. distant from one another. In many instances the membrane between the conuli is not homogeneous but sieve-like, the pores being very conspicuous. All the primary fibres are overcharged with foreign bodies, this property rendering them of irregularly angular outline; some of the secondary fibres are devoid of any enclosures, others on the contrary being more or less covered with sand-grains, fragments of spicules, &c., and often a fine secondary fibre shows an extension in its middle, owing to the presence of a sand-grain many times larger than the diameter of the fibre itself. It may also be added that, as in *Hircinia variabilis* according to F. E. Schulze,[1] the primary fibres in my *Cacospongia amorpha* show a tendency to form meshes.

Colour.—Outer surface grey, parenchyma butter-like, skeletal fibres pale brownish-yellow.

Habitat.—Bahia, shallow water.

Cacospongia murrayi (Pl. IV. fig. 3; Pl. VI. fig. 8).

It is really very agreeable, after such a bad species as that just described, to pass on to the description of such a *bona species* as *Cacospongia murrayi*. The single specimen on which this species is founded is represented on Pl. IV. fig. 3, the skin of one part being stripped off. The external surface is smooth throughout, and is represented by a rather thick dermal membrane, which, owing to the great number of foreign

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxxiii. pl. iii. fig. 1, 1880.

bodies enclosed, differs obviously both in colour and consistence from the proper parenchyma, and can be easily drawn off. This peculiarity is of course of very doubtful importance. I have very often had occasion to speak of the low systematic significance of similar properties of the skin, and it is sufficient to peruse the lines which F. E. Schulze devotes to the matter in his paper on *Hircinia*[1] in order to become convinced that species based on such characters are very doubtful. The more the dermal membrane is charged with foreign bodies the more easily can it be drawn off, and on the other hand it is obvious that the number of foreign bodies enclosed in the membrane depends on the nature of the surrounding ground.

Of course it cannot be denied that the tendency to form such a cortex of foreign bodies may become hereditary, but still its systematic application appears to me to be rather dangerous; and with respect to my *Cacospongia murrayi*, it is the less necessary as the sponge shows another peculiarity of an undoubtedly more constant character, concerning the structure of the skeleton. In *Cacospongia murrayi* the skeleton is, so to speak, composed of two skeletons. There are vertical primary fibres 0·15 mm. in diameter, and rather finer secondary fibres united to the first-mentioned in a more or less regular horizontal direction, and this system of primary and secondary fibres is enveloped in an irregular network of still finer fibres (0·015 mm. in diameter on an average), originating both from primary and secondary ones, but forming far smaller meshes. Pl. VI. fig. 8, representing the outer surface of a portion of skeleton, when seen against the light, illustrates this peculiarity sufficiently well. The outermost points of the primary fibres are either pretty well developed, and accordingly project from the outer surface into the substance of the cortex, without giving rise, however, to any unevenness on its outer surface, or are very short, and represented only by low thickenings over the intersecting point of the primary and the uppermost secondary fibres. The histological character of the cortex presents no deviations from the usual connective tissue of Keratosa, except that the cellular elements, stellate and fusiform cells, are very scanty; the histological and anatomical structure of the proper parenchyma is that of typical Spongidæ.

The species is named in honour of Mr. John Murray of the Challenger Expedition.

Colour.—Outer surface grey, parenchyma pale greyish, skeletal fibres brownish.

Habitat.—Station 163B, June 3, 1874, off Port Jackson; depth 35 fathoms, hard ground.

Cacospongia vesiculifera, n. sp. (Pl. IV. fig. 2; Pl. VI. fig. 9).

This form, like the one just described, is represented in the Challenger Collection by a single specimen, and is in its turn provided with a special cortex, but here its

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxxiii. p. 14, 1880.

presence alone justifies the establishment of a new species; this mainly owing to its histological peculiarities. Apart from the foreign enclosures, its constituent parts are scantily developed transparent ground-mass, and in this latter large vesicular cells of round or more oval form, 0·02 mm. in diameter, not dissimilar to the renowned and still debatable "Schleimzellen" of Mollusca, as Dr. Flemming[1] has drawn them, and thoroughly identical with the vesicular cells of many Desmacidonidæ—undescribed indeed hitherto, but undoubtedly very well known to every spongiologist who has had to deal with the representatives of the family just mentioned. A portion of the cortex with such cells is shown in the annexed woodcut.

But the sponge also possesses some other characters which render it readily distinguishable from other Keratosa, its skeleton recalling that of a *Spongelia* rather than that of *Cacospongia*, and its external shape being perhaps also of some systematic value. The sponge has been found in the form of a thick-walled tube, with very narrow central cavity, ending in a small osculum. The outer surface is rough and provided with rounded tubercles corresponding to the prominent secondary fibres. There are in this sponge three kinds of skeletal fibres—(1) gastric vertically directed primary fibres, in most cases more or less loaded with foreign bodies, and on an average 0·2 mm. thick; (2) centrifugal secondary fibres, originating from the primary ones, and in their direction towards the outer surface forming with the last mentioned, if from above, a more or less acute angle, and with an average diameter of 0·1 mm.; and (3) still finer (0·06 mm.) tertiary fibres uniting the secondary and primary ones; to sum up, this is a kind of skeleton very common in Spongelidæ, but exceptionally rare in Spongidæ. The secondary and tertiary skeletal fibres proved to be free from any enclosures. Apart from the vesicular cells there are no other histologically or anatomically deviating peculiarities to be stated.

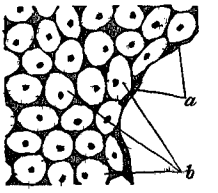


FIG. 2.—Cortex of *Cacospongia vesiculifera*. *a*, pavement epithelium of a subdermal cavity; *b*, vesicular cells.

Colour.—Outer surface dirty greyish, parenchyma pale yellowish-white, skeletal fibres straw-yellow.

Habitat.—Off Port Jackson, April 1874; depth 7 fathoms.

Cacospongia procumbens, n. sp. (Pl. VI. fig. 6).

This species—a *Sarcotragus* in the sense of Oscar Schmidt—possesses a very curious skeleton. In *Cacospongia vesiculifera* we have had to deal not only with primary and secondary, but also with tertiary skeletal fibres; here there are not even primary and secondary ones. The sponge has been found in the form of a crust, and its supporting

[1] Die Bindesubstanz der Mollusken, pl. i.

apparatus is represented by a large meshed thoroughly irregular basal network of the skeletal fibres, with numerous ascending branches directed towards the outer surface, with a denticulated appearance due to conuli, about 0·75 mm. high and 3 to 4 mm. distant from one another. All the fibres are approximately of the same thickness (0·18 mm. on an average), and all cored in their central part, very scantily, however, with foreign bodies. As before remarked, the species would be referred by O. Schmidt to his subgenus *Sarcotragus*, the filaments filling its parenchyma being very thin and fine.

In the skin are numerous fragments of siliceous spicules.

Colour.—Parenchyma pale brownish, skeletal fibres deep brown.

Habitat.—H.M.S. "Porcupine," Station 13, 1870, off the coast of Portugal; depth 220 fathoms.

Cacospongia dendroides, n. sp. (Pl. VIII. figs. 1–3; Pl. VI. fig. 14).

There are in the Challenger collection three specimens, all of a rather Spongeloid shape, and from the same locality, but presenting some distinctions in the structure of their skeleton, so that a subdivision at least into varieties is necessary. One of the specimens is represented on Pl. VIII. fig. 1, and therefore a further description of its general form is superfluous. The other specimens all agree as to their external shape with the one just mentioned, but while the skeleton of this latter (Pl. VI. fig. 14) is composed of an irregular network of comparatively thick and yellow coloured fibres, the skeletons of the two other specimens, which do not differ from the former as to the general character of the network, are composed of fibres twice as thin, forming meshes approximately twice as large as in the former case, and not of a yellow colour but white. Is this a character of individual or of varietal, or of specific significance? I must confess I am not prepared to decide the question, and think it advisable to choose the middle course by establishing two provisional varieties—*dura* for the specimen with more solid fibres, and *friabilis* for the two remaining. In both cases all the skeletal fibres proved to be more or less cored with foreign enclosures. All the three specimens have proved to be full of filaments, and it was in two of them that I found out those dumb-bell-shaped corpuscles to which I have referred on page 14.

If amongst the skeletal fibres of this form the primary—vertically directed—can be still distinguished owing to their comparative thickness, it must yet be added that such a distinction is of a rather conditional character, the skeleton presenting the aspect of a pretty irregular network.

Colour.—Pale yellowish-white.

Habitat.—Station 208, January 17, 1875, lat. 11° 37′ N., long. 123° 31′ E.; depth 18 fathoms, blue mud.

Cacospongia spinifera, n. sp. (Pl. VI. fig. 12).

Had the genus *Oligoceras* been retained it would have been necessary to refer the species I am going to describe to that genus. The outer surface of the single specimen representing this new species in the collection is indeed a contrast to *Oligoceras collectrix*, being quite devoid of any foreign bodies, but they are abundant in the parenchyma, and on the other hand are so richly represented in the skeletal fibres that these latter are extremely poor in true horny substance. Again as to the external aspect of its skeleton,—apart from the point that it is not represented by isolated standing trees as in *Oligoceras collectrix*,—it recalls vividly that of the form just mentioned. The large size of the meshes, the tendency of the fibres to ramify—all this approximates the form I am now describing to *Cacospongia* (*Oligoceras*) *collectrix*. There is, however, a character which permits a pretty sharp diagnosis of the species; I mean the nature of its outer surface. The latter, in spite of the great friability of the skeleton and its general tendency to disappear entirely, is still provided with very high conuli (4 to 7 mm.), so that, if drawn, this specimen would give precisely the same impression as the drawing given by Hyatt for his *Hircinia acuta*,[1] and this not only with regard to the character of the outer surface, but also that of the external shape of the sponge in general. The specimen must have died at the moment when its dermal pores were open, and thus the whole of its outer surface is of a sieve-like appearance in the proper sense of the word. Apart from the point that, like the preceding form, this specimen proved to be overloaded with filaments, their heads being of elongated form and reaching 0·06 mm. in length and 0·04 mm. in breadth on an average, there are no histological nor anatomical peculiarities of interest to be stated.

Colour.—Outer surface brownish-grey, parenchyma pale greyish, skeletal fibres black.

Habitat.—Station 177, August 18, 1874, lat. 16° 45′ S., long. 168° 7′ E.; depth 130 fathoms, volcanic sand.

Cacospongia tuberculata, n. sp.

So far as the properties of the skeleton are concerned (apart from the fact that the fibres are not black but pale yellow), this species seems to be closely allied to *Cacospongia spinifera*. Indeed, in most cases the primary fibres do not ramify at all, but ascend vertically, and are united with one another by horizontal secondary fibres, these latter, as in *Cacospongia spinifera*, beginning very often with flat extensions; yet, here and there ramifying fibres have been found, their secondary obliquely directed branches instead of reaching the neighbouring primary fibres ending freely. There is, however, one character

[1] Revision, &c., vol. ii. pl. xv. fig. 20.

in the two specimens by which the species is represented, admitting probably of a tolerably good distinction of the form in question from *Cacospongia spinifera*. It is the appearance of the outer surface, which is here not spinous but provided with rounded tubercles. How far this peculiarity permits the establishment of a new species is difficult to say; at any rate I see at the present time no other course open but to separate the form in question by the establishment of a new species.

Both the specimens proved to be full of filaments, here, however, with heads of a rather different shape from that of the filament-heads in my *Cacospongia spinifera*, being of a more roundish outline, and with an average diameter of 0·055 mm. One of the specimens proved to be quite compact, the other, as in *Cacospongia cavernosa*, was pierced by numerous large internal channels inhabited by Chætopoda.

Colour.—Outer surface greyish, parenchyma white, skeletal fibres pale yellow.

Habitat.—Station 162, April 2, 1874, off East Moncœur Island, Bass Strait; depth 38 fathoms, sand and shells.

Cacospongia intermedia, n. sp. (Pl. VI. fig. 7).

I have already taken occasion to mention (p. 27) this species as presenting to the classifier many difficulties. The meshes formed by its skeletal fibres being rather large, and the fibres themselves thick, the form must be referred to *Cacospongia;* but the fibres are almost all of the same diameter (0·35 mm.), and it is only in the prominences of the outer part of the skeleton that an approximate distinction between primary and secondary fibres is possible. This character recalls the *Coscinoderma* of Carter; on the other hand, the body of the sponge is broken through by numerous canals, the character of the outer surface of the skeleton is that of *Hippospongia*, the distinction between primary and secondary fibres, as already stated, is pronounced only in the tufts; all this would justify the placing of this sponge in the genus *Hippospongia*, provided that one could prove the importance of the characters just mentioned to be greater than that of the skeletal fibres being thick and the meshes formed by them large. So far as to the general position of the form in question. Now it must be mentioned that apart from the thickness of the skeletal fibres and the largeness of their meshes, the sponge recalls vividly *Euspongia vermiculata*. What systematic place is to be assigned to it? Of course merely a provisional one, and accordingly the task of the classifier is reduced to giving a detailed description of it.

The species is represented in the collection by a single specimen of irregularly massive form; the outer surface is smooth and even, the dermal membrane enveloping the skeleton with its external outgrowths in the same manner as in *Hippospongia anomala*. In many spots the dermal membrane is pierced by larger or smaller (2 to 4 mm.) openings, sometimes disposed by threes or fours together, sometimes lying isolated; whether some of these openings are really oscula is difficult to say without a complete destruction of

the specimen; but this is certain, that most of them are "pseudo-stomata," leading into the canals separating the body of the sponge, and the envelope of whose walls is merely the continued dermal membrane. The properties of the skeleton have been already discussed, and I hope that with the help of the figure given on Pl. VI. its characters will be rendered obvious; its outer surface recalls that of *Hippospongia mauritiana* (Pl. VI. fig. 3), apart from an entire absence of bundles of parallel fibres.

Colour.—Outer surface black, parenchyma greyish, skeletal fibres brown.

Habitat.—Station 177, off Api, New Hebrides, August 18, 1874; depth 130 fathoms, volcanic mud.

Cacospongia irregularis, n. sp. (Pl. VI. fig. 10; Pl. VIII. fig. 5).

The chief peculiarity of this curious species consists in this property of its skeleton, that, in contrast to all other Spongidæ, the bundles of its fibres are so closely and irregularly intertwined that the distinction of primary and secondary ones is entirely impossible; they form a kind of irregular network, its meshes being not represented by internal channels as in *Hippospongia*, but filled by parenchyma. The species is represented in the collection by a single specimen, apparently of irregularly massive form, in reality provided with large internal cavities, so that the sponge can be compared to a casket. The surface is smooth, but not devoid here and there of outgrowths corresponding to the prominent tufts of skeletal fibres, presenting a compact network, and in most cases ending more or less sharply. As to the secondary meshes of the skeleton, they are quite irregular, and my drawing (Pl. VI. fig. 10) will give a better explanation of them than any words. The primary meshes, *i.e.*, meshes formed by the skeletal fibres themselves, are in most cases small, but in others very large, and occasionally a mesh is represented by two bundles forming an acute or obtuse angle and a single usually thick fibre. The thickness and length of the fibres are very variable, but all agree with one another as to their tendency to take in foreign bodies. The specimen proved to be overcharged with filaments, one of which is represented on Pl. VIII. fig. 5.

Colour.—Outer surface and parenchyma pale dirty yellowish, skeletal fibres pale grey-yellowish.

Habitat.—Station 188, September 10, 1874, lat. 9° 59′ S., long. 139° 42′ E.; depth 28 fathoms, green mud.

Cacospongia oligoceras, n. sp. (Pl. VI. fig. 13).

This species is represented only by a small fragment of massive shape, with the outer surface, where not covered with mussel-shells, stones, &c., provided with low conuli. Its exterior agrees closely with that of *Oligoceras collectrix*, Schulze, but there is a great

difference with regard to the structure of the skeleton; in *Oligoceras collectrix* the skeleton is represented by small isolated horny trees, and there are parts in the body where no skeleton is to be found at all; in the species I am describing it is present everywhere, but though a continuous network, is very often interrupted by large, enclosed, foreign bodies. The skeletal fibres are full of fragments of spicules, sand-grains, &c.; their form, whether cylindrical or flat, as well as the size of the meshes formed by them, is very variable. A portion of the skeleton ($\times 2$) is represented on Pl. VI. fig. 13. The thickness of its fibres, vertical and horizontal indiscriminately, varies from 0·06 to 1 mm.

Colour.—Outer surface greyish, parenchyma butter-yellowish, skeletal fibres white.

Habitat.—Station 208, January 17, 1875, lat. 11° 37′ N., long. 123° 31′ E.; depth 18 fathoms, blue mud.

Cacospongia compacta, n. sp. (Pl. VI. fig. 11).

The external shape of the single specimen representing this species in the Challenger collection recalls that of *Euspongia officinalis*, var. *lobosa*, but of course this coincidence is of no further consequence, the form in question showing the closest affinities to *Cacospongia oligoceras* just described. There are, however, the following distinctions: the meshes in the former are comparatively large; in the latter they are so very narrow that the whole skeleton at first sight appears to be a compact mass (comp. Pl. VI. fig. 11); in both cases the horny substance is scantily developed, the chief foundation of the skeletal fibres being represented by foreign enclosures, but while the fibres of *Cacospongia oligoceras* and its whole skeleton are friable, those of *Cacospongia compacta* are rigid and hard. Again, when a fibre of the former is seen under the microscope, it gives the impression that the taking in of foreign bodies has been influenced by the kind of growth of the fibre; they are disposed in it as if following certain laws of distribution, and although overloaded with them, the fibres still possess a rather smooth surface. It is a strained expression to speak of differentiated skeletal fibres with regard to *Cacospongia compacta*; a portion of its skeleton when magnified conveys the impression as if there were previously some sand-grains disposed in the parenchyma without any order, and these sand-grains were latterly enveloped in a continuous mass of horny substance. Here a large sand-grain, and immediately as a continuation of this thickening a short piece of a typical horny fibre without any enclosures, finishing again with a new similar thickening.

We are hitherto in complete uncertainty as to the systematic value of the colour of the horny substance in these and other cases. But if it be of consequence, this character alone would justify the separation of both the forms compared; in *Cacospongia oligoceras* it is colourless, while in the species I am characterising it is of an intense yellow colour.

The specimen proved to contain filaments, not being, however, particularly rich in them.

Colour.—Soft parts dirty white, skeletal-fibres brownish-yellow.

Habitat.—Bahia; shallow water.

Cacospongia collectrix, F. E. Schulze, sp.

Oligoceras collectrix, F. E. Schulze, Zeitschr. f. wiss. Zool., vol. xxxiii. p. 34.

The two Challenger specimens which I group in this species are so different in external shape that, should we classify the Keratosa according to their form, we should be obliged to refer them, at least, to different genera. Yet it is well known that in most cases the external shape as well as the colour in the Porifera are of extremely subordinate consequence, and I am the more inclined to regard both the specimens in question only as individuals of the same species, as in the Dalmatian specimen of *Cacospongia collectrix* described by F. E. Schulze we find a form of, so to speak, neutral characters with respect to the differences above mentioned. These differences concern the mode of growth and the quantity of foreign bodies enclosed in the parenchyma. The Dalmatian specimen just alluded to is represented in Prof. Schulze's paper on pl. ii. fig. 6, and one can see that is not crust-like but of massive shape. On pl. iii. fig. 7, Prof. Schulze gives also a drawing of the anatomical organisation of the specimen in question, and this drawing renders obvious that, contrary to the specific designation of *collectrix*, its soft parts are comparatively free from foreign enclosures. This latter character is common to the Challenger specimen of *Cacospongia collectrix* from the Philippine Islands, while as to its external shape this specimen has been found in the form of a crust. On the contrary, the second Challenger specimen (from Japan) recalls vividly, so far as its exterior is concerned, F. E. Schulze's specimen from Lesina, but its soft parts proved to be overloaded with foreign enclosures, almost exclusively sand grains often 2 to 3 mm. in diameter. It is therefore plain that the above differences may be important enough to justify the subdivision of the species into independent varieties, but in no case of a greater consequence. All this, however, on the supposition that *both* our specimens are really closely allied to *Cacospongia collectrix*, F. E. Schulze. So far as the specimen from the Philippine Islands is concerned this is beyond doubt. This specimen, together with the mussel-shells which it coats, is also of a rather lumpy, massive form; a more attentive examination shows, however, that this is due simply to the aggregation of the mussel-shells, and that the sponge itself is of a well-marked crust-like appearance, sometimes as thin as a leaf of paper. Now, while in some parts of it no skeleton is to be discovered at all, the others are propped by small (2 to 7 mm. high and about 0·5 mm. thick), isolated horny trees very rich in enclosed

foreign bodies—all precisely as in the original specimen of the form from Lesina; and as its internal organisation also does not deviate from that of *Cacospongia collectrix* as described by F. E. Schulze, there is no room to doubt the specific identity of both these specimens. But the matter is quite different with regard to the Challenger specimen from Japan. Its internal structure also does not differ from that of a typical *Euspongia* or *Cacospongia*, but—and this is the salient point—I was unable to make out whether this specimen really does possess any differentiated horny skeleton. This was owing to its minuteness, its dimensions being on an average as follows:—length 22 mm., height 7 mm., breadth 10 mm. The half of the specimen has been sacrificed to the decision of the above question; the result of a lasting treatment with hot water and ammonia was a heap of sand-grains and a single 2 mm. high horny tree also very rich in foreign enclosures. Is it to be regarded as produced by the sponge itself? Is it also nothing but a foreign enclosure, like what Marshall states [1] of the specimens of *Psammopemma densum* he had for examination? All this remains an open question. That our specimen is a horny sponge is quite plain, the foreign bodies enclosed in its parenchyma being undoubtedly surrounded with obvious horny substance; that, being a Keratose sponge, it is also a Spongid is demonstrated by its internal structure, but whether it is to be classed in the species *Cacospongia collectrix*, and not to be regarded as an analogue of *Psammopemma* in the family of Spongidæ, will be decided but by later investigations. Of course under such circumstances I prefer to abstain from the creation of a new name.

Both the specimens proved to contain filaments, but while the specimen from Japan is strikingly poor in them, the specimen from the Philippine Islands on the contrary is overloaded with them in not a less degree than the Challenger specimens of *Stelospongos longispinus* or *Cacospongia irregularis*.

Colour.—Specimen from Philippine Islands, pale greyish-yellow. Specimen from Japan, outer surface grey, parenchyma dirty yellowish.

Habitat.—Station 203, October 31, 1874, lat. 11° 6′ N., long. 123° 9′ E.; depth, 12 to 20 fathoms; mud. Station 233A, May 19, 1875, lat. 34° 38′ N., long. 135° 1′ E.; depth, 8 to 50 fathoms; sand.

Stelospongos, O. Schmidt.

Spongidæ with comparatively thick skeletal fibres united in separated columns directed more or less regularly radially from the basis of the sponge towards the outer surface, and consisting each of a compact network of vertical, primary, and horizontal secondary fibres.

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxxv. p. 114.

Stelospongos longispinus, Fonbressin et Michelotti, sp. (Pl. VI. fig. 15; Pl. VIII. fig. 4).

Polytherses longispina, Fonbressin et Michelotti, Spongiaires de la mer Caraïbe, p. 71.
Hircinia acuta, var. *longispina*, Hyatt, Revision, &c., vol. ii. p. 549.

The descriptions of Fonbressin and Michelotti and Hyatt agree closely with the properties of one specimen of the Challenger collection, and I have no doubt that I am right in identifying it with *Hircinia acuta*, var. *longispina* of Hyatt. How far the other varieties of this species distinguished by Hyatt are really to be referred to the genus *Stelospongos*, I am not prepared to say, but it is obvious that the conjectural variety we are speaking of is a true *Stelospongos*. Hyatt himself says, "In fact, so strong is the resemblance (between a *Stelospongos* and the form in question) that it was at first classified with that genus," but constant to his dermal-membrane theory of the formation of the skeleton, he assigned to the form another systematic position. Now we know that the theory just cited is false, and a different procedure is necessary. Indeed, when compared with *Stelospongos maynardii*, or any other true *Stelospongos*, our specimen is not a typical representative of the genus. It is but seldom that one can distinguish in the columns constituting the skeleton—some of which are represented on Pl. VI. fig. 15—the vertical primary, and more or less horizontal secondary, fibres, but in some instances this distinction is still evident, and accordingly there can be scarcely any objections to the proceeding adopted here.

The specimen proved to be full of sperm-balls, and in a far greater degree of filaments, one of which is represented on Pl. VIII. fig. 4.

Colour.—Outer surface dark grey, parenchyma dirty white, skeletal-fibres pale yellow.

Habitat.—Off Barra Grande, September 10, 1873; depth, 400 fathoms; red mud.

Carteriospongia, Hyatt.

Spongidæ of flabellate, leaf-like, or funnel-shaped form, with skeletal-fibres admitting of a distinction into larger primary and smaller secondary ones, with flagellated chambers usually devoid of any inhalent and exhalent canaliculi, with ribbed outer surface.

Carteriospongia radiata, Hyatt (Pl. IV. fig. 5; Pl. V. figs. 7, 8, 9).

Carteriospongia radiata, Hyatt, Revision, &c., vol. ii. p. 541.

There are in the Challenger collection four specimens of the genus *Carteriospongia*, three funnel-like, the fourth presenting a colony of leaf-like individuals, which with regard to the properties of their skeleton—except that the "veil" of Hyatt proved to be propped up not by a network of skeletal fibres but by foreign enclosures—and to those of the outer

surface agree so closely with Hyatt's *Carteriospongia radiata*, var. *dulsiana*, that I have but to refer the reader to the description above mentioned, and wish only to elucidate the anatomical and histological characters of the internal organisation of this interesting species. So far as these latter are concerned, some details have been already given (pp. 17, 18), and it now remains to expose them coherently. Through the pores, inconspicuous to the naked eye and scattered on both surfaces of the animal, the water reaches, as usual, more or less developed subdermal cavities; but these latter, instead of ramifying by forming smaller and more numerous canals (as is the case in *Aplysina* and to a certain degree also in *Euspongia* and other allied genera), in most cases communicate immediately with the flagellated chambers; the dendroid character of these ramifications is here quite lost. The flagellated chambers (all larger than those of true Spongidæ, but still of hemispherical shape) having received the water by means of numerous pores in their walls, expel it, not by means of special canaliculi as is the case in the true Spongidæ, but through a large opening like that in the flagellated chambers of Spongelidæ. The water having left the flagellated chambers enters large exhalent lacunæ of variable outline, and many of these latter uniting together throw it out through the oscula—in the Challenger specimens all on the *internal* surface; in some funnel-shaped specimens in the British Museum, on the contrary, all on the *external* surface. It is an interesting fact that when the sponges are of a leaf-like form, the exhalent orifices are always more or less concentrated on one surface only. In *Ianthella* they are indeed to be found on both surfaces, but still their distribution is not equal—they are numerous on one surface, but very scanty on the other. The properties of the internal organisation are thus rather deviating from those of typical Spongidæ; again, as to the histological structure of the form in question, it differs also from that of true Spongidæ, its ground-mass being almost entirely devoid of granules in the neighbourhood of the flagellated chambers. To the conjectural systematic significance of these differences many pages have already been devoted; we have nevertheless come to the conclusion that at last, provisionally, the genus must be still grouped in the family Spongidæ, owing to the presence of those enigmatic "Stränge" of cells which have been recently described by F. E. Schulze, and which, in spite of a remark of this naturalist as to their entire absence in some individuals of *Euspongia* or *Cacospongia*, I am yet inclined to regard as very characteristic of the whole family. In *all* the Spongidæ I have had the opportunity of examining I found them, and if absent in one region of the body they are still to be found in other parts of it.

One of the specimens examined proved to be full of sperm-balls, one of which in a ripe state is represented on Pl. V. fig. 9. I was able to discern also the preceding stages of their development, but I abstain from their description here, since I shall return to the matter when describing the spermospores of *Verongia*.

Colour.—Pale dirty yellowish.

Habitat.—Off Wednesday Island, Cape York, September 8, 1874; shallow water.

Carteriospongia otahitica, Esper, sp. (Pl. IV. fig. 4).

Spongia otahitica, Esper, Pflanzenthiere, Bd. ii. p. 270.
Carteriospongia otahitica, Hyatt, Revision, &c., vol. ii. p. 541.

This species, represented in the collection by numerous specimens from Admiralty Islands, was established in the year 1794, and there are in spongiological literature many descriptions of it. Accordingly, I consider it unnecessary to enter here into particulars, and refer the reader to the best of these descriptions, that of Hyatt, in the hope that with the help of my drawing on Pl. IV. the characters of the species may be easily comprehended.

Colour.—Dirty pale yellowish.

Habitat.—Off Wild Island, Admiralty Islands; reefs; March 1875.

Family APLYSINIDÆ, Vosmaer.

Aplysinæ (e.p.), Hyatt.
Ceratina (e.p.), Carter.
Aplysinidæ (e.p.), F. E. Schulze, v. Lendenfeld.

Keratosa with small either hemispherical or pear-shaped flagellated chambers communicating with exhalent and inhalent cavities, each by means of one comparatively long and narrow inhalent and exhalent canaliculus. Axis of fibres thick; ground-mass in the neighbourhood of the flagellated chambers overloaded with granules.

Luffaria, O. Schmidt.

Aplysinidæ with thick-walled heterogeneous skeletal fibres, their central part but little differentiated optically from the surrounding horny lamina.

Luffaria variabilis, n. sp. (Pl. IX. figs. 1–6).

As I remarked before (p. 33), I am not prepared to say whether all *Luffariæ* in addition to thick skeletal fibres also possess fine ones. But should such be the case, the species I am going to describe may still be readily distinguished from all others of the genus by the following peculiarities; its skeletal fibres are not at all so glass-like and fissile as Schmidt states with regard to the specimens he had for examination. Again, though on the whole its skeleton admits of comparison with a burst but still only with a very imperfect one, the distance between the prominent outer fibres reaching 1 to 2 mm. In addition to some small fragments, the species is represented in the Challenger collection by two specimens, one of massive shape, the other on the contrary

in the form of three elongated stalks connected together at their bases. I do not think that this difference in external appearance can justify the establishment of two varieties; for in the structure of their soft parts (quite identical with that of *Aplysina*), and again in that of the skeleton, the specimens do not differ at all. Indeed the colour of the parenchyma in one case (massive specimen) is rather yellow, in the other greyish, but I am not inclined to ascribe any consequence to this difference. Both the specimens are represented on Pl. IX. I have nothing further to add to this illustration, and as to the properties of their skeleton in general and to those of their skeletal fibres I refer the reader to page 7 of this report.

Colour.—Outer surface greyish, parenchyma yellow and dirty greyish-white, skeletal fibres brownish-yellow and brownish.

Habitat.—Station 177, August 18, 1874, off Api, New Hebrides; depth 60 to 70 fathoms. Off Tahiti; reefs; September 1875.

Verongia, Bowerbank.

Aplysinidæ, the central axis of whose thick-walled skeletal fibres is readily to be distinguished optically from the surrounding horny walls.

Verongia hirsuta (?), Hyatt (Pl. X. figs. 1–3).

Verongia hirsuta, Hyatt, Revision, &c., vol. i. p. 403.

I leave to later investigators the decision of the question whether the form I am going to describe is identical with *Verongia hirsuta*, var. *fistularoides* of Hyatt. His description is very short, and there are no explanatory illustrations; it agrees, however, closely with what I can give of the form in question. I myself indeed should call the meshes of the skeleton regular, but with regard to this difference the utmost caution is advisable. In *Verongia fistularis* (*Spongia fistularis*, Linné) from the Museum of Erlangen, which both Hyatt and myself were able to obtain for the purpose of comparison, and which is placed by Hyatt in his family Dendrospongiadæ, characterised *inter alia* by irregularity of the meshes, I was able to discern meshes of a geometrically regular polygonal character, and again meshes sometimes of irregularly round, sometimes of irregularly oval, shape.

As to the anatomy of the form, I am glad to confirm the supposition of Vosmaer[1] that it does not differ from that of *Aplysina;* the exposition of the canal-system on Pl. X. fig. 7 has been made after a preparation of *Verongia tenuissima*, but it may be applied also to *Verongia hirsuta*, the more so as both the specimens of *Verongia hirsuta* and *Verongia tenuissima*, represented in the collection each only by a single

[1] On *Velinea gracilis*, p. 444.

specimen, proved to be full of spermospores. To a more detailed description of these latter I shall return later, and will now merely call attention to this peculiarity of the skeletal fibres of my *Verongia hirsuta*, that they almost all proved to be covered with small plates of polygonal outline as represented on Pl. X. fig. 3; I have been unable to make out their origin. Occasionally, and particularly on young fibres, I found no such plates, but small drops of yellow substance at a comparatively great distance from one another. I can but state, and this with the greatest certainty, that these plates are not modified spongoblasts. I regard them as the last product of the spongoblasts, ready to lose their spongoblastic properties in order to become common stellated cells.

Colour.—Pale rose-brownish, skeletal fibres dark brown.

Habitat.—Off Bermudas, June 1873; reefs.

Verongia tenuissima, Hyatt (Pl. X. figs. 4–7).

Verongia tenuissima, Hyatt, Revision, &c., vol. i. p. 403.

Hyatt's work upon the Keratosa is so very poor in explanatory illustrations that although the short diagnosis he gives to his *Verongia tenuissima* is entirely applicable to the form I am going to describe, I do not feel quite certain whether both these forms are identical, but if not, at any rate they are very closely allied to one another, and to be probably distinguished merely as different varieties of the same species.

The form is represented by a single specimen. It is of fistular shape, the central cavity being funnel-like, with a circular upper extension of 22 mm., and the walls 20 mm. thick in the basal and middle parts of the body, growing rather thinner towards its upper end. The inner surface, in contrast to that of *Verongia hirsuta*, is smooth but undulating, while the outer surface is hilly; the surface both of hillocks and depressions being shagreen-like, and studded with projecting points of the skeletal fibres. These latter—in thorough harmony with Hyatt's statement on the point—are far thinner and more elastic than those of *Verongia fistularis*, yet at least one and a half times as thick as the fibres of *Aplysina aërophoba*; their average diameter is 0·2 mm., and the meshes formed by them recall vividly in size and shape those of *Aplysina*. The internal organisation, both anatomical and histological, agrees so closely with that of *Aplysina aërophoba* that having illustrated it by a small drawing (Pl. X. fig. 7), I can refer the reader to F. E. Schulze's paper on the Aplysinidæ. I must add, however, that I was not able to discern the bundles of fibrils which he describes[1] and represents on pl. xxii. fig. 14. of his paper. But I was fortunate enough to discover the male generative product, the spermospores; and this both in *Verongia hirsuta* and *Verongia tenuissima*, in this latter form together with ova, scantily scattered in the peripheral parts of the body, while the spermospores have been found everywhere and in abundance. I call them

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxx. p. 397.

spermospores and not sperm-balls, as I did in the description of *Carteriospongia radiata*, for they are quite different in appearance and structure. In *Carteriospongia radiata*, and in other instances, these formations present an aggregation of cells, if not ripe spermatozoa, these cells being each equivalent to the other, and the whole lying in a capsule formed by numerous pavement cells; in *Verongia* the analogous capsule is formed by a *single* cell, the endothelium is not to be found at all. In one word, the male generative products are quite equivalent to those of Calcarea as I have described them in *Sycon raphanus*.[1] I must confess I can find no explanation of this; the matter appeared to me strange even before, when I thought the Calcarea were opposed in this respect to the *whole* group of Silicea. I was thoroughly startled when, hand in hand with indubitable sperm-balls in *Carteriospongia* as well as in some other Keratosa of the collection, I discerned in my preparations of both species of *Verongia* the most typical spermospores. I was not able to follow out their development, but when ripe they recall so vividly the corresponding formations in *Sycon raphanus* (with the sole distinction that while in this latter instance the nucleus of the covering cell in quite ripe spermospores is in most cases indistinct, in *Verongia* I find quite empty capsules, nevertheless, provided with it) that I *must* identify both these formations; on the other hand, I have now no doubt that at the development of the *sperm-balls* no covering cell is formed, that its description by F. E. Schulze[2] agrees closely with the reality. I have repeatedly examined *Oscarella* (*Halisarca*) and *Aplysilla*, and was able to follow out the development of their sperm-balls from the first beginning, and I can only affirm the former statements of F. E. Schulze, that we have in these instances to do with real division of the sperm cells, and that there is no covering cell to be discerned. On the whole the enigmatic question requires a special and extensive investigation, the more so that it is not only of spongiological but also of general interest.

Colour.—External surface black, that of the central cavity and parenchyma grey, skeletal fibres brownish yellow.

Habitat.—Off Barra Grande, September 10, 1874; depth, 400 fathoms.

A perusal of the preceding pages shows that of thirty-four determinable forms brought home by the Challenger Expedition, almost two-thirds (21) have been found to be new, and that only three species (*Psammopemma densum*, *Luffaria variabilis*, and *Cacospongia collectrix*) were obtained from more than one locality. Under such conditions any discussion of the geographical distribution of the Keratosa would be possible only if extended over all the Keratosa hitherto described. It must be said, however, that on

[1] *Sitzungsb. Akad. d. Wiss. Wien*, Bd. lxxxvi., 1882.

[2] *Zeitschr. f. wiss. Zool.*, Bd. xxviii, p. 24, pl. iii. fig. 19.

the whole, our knowledge of the group is in this direction so very fragmentary that even in this case the possibility of any deductions and generalisations is entirely excluded. The annexed Table has, accordingly, no other object than to render conspicuous the comparative richness in Keratosa of the different localities visited by the Challenger, as well as the depths from which they have been obtained. The depth (in fathoms) is indicated by the figures in the columns, s.w. = shallow water.

BATHYMETRICAL TABLE.

	Portugal.	Bermudas.	Nova Scotia.	Brazil.		Tristan da Cunha.	Eastern Coast of Australia.			New Hebrides.	Wednesday Island.	Admiralty Islands.	Philippine Islands.	Japan.	Honoruru.	Tahiti.
				Barra Grande.	Bahia.		Bass Strait.	Port Jackson.	Torres Straits.							
Ianthella flabelliformis, Pallas,									28							
Spongelia spinifera, F. E. Schulze,								7								
,, *pallescens*, O. Schmidt,					s.w.											
,, *horrida*, Selenka,									8							
Psammoclema ramosum, Marsh.,							38–40									
,, *vosmaeri*, n. sp.,									8							
,, *foliaceum*, n. sp.,							38–48									
Psammopemma densum, Marsh.,			83					7								
,, *porosum*, n. sp.,					s.w.											
Coscinoderma confragosum, n. sp.,	220															
,, *denticulatum*, n. sp.,															s.w.	
,, *altum*, n. sp.,						60										
Euspongia officinalis, Linn., var. *lobosa*, n. var.,					s.w.											
Hippospongia anomala, n. sp.,									8							
,, *mauritiana*, Hyatt,										60–70						
Cacospongia levis, n. sp.,				400												
,, *amorpha*, n. sp.,					s.w.											
,, *murrayi*, n. sp.,								30–35								
,, *vesiculifera*, n. sp.,								7								
,, *procumbens*, n. sp.,	220															
,, *dendroides*, n. sp.,													18			
,, *spinifera*, n. sp.,										60–70						
,, *tuberculata*, n. sp.,							38–40									
,, *intermedia*, n. sp.,										60–70						
,, *irregularis*, n. sp.,									28							
,, *oligoceras*, n. sp.,													18			
,, *compacta*, n. sp.,					s.w.											
,, *collectrix*, F. E. Schulze,													12–20	8		
Stelospongos longispinus, Duch. and Mich.,				400												
Carteriospongia otahitica, Esper,												s.w.				
,, *radiata*, Hyatt,											s.w.					
Luffaria variabilis, n. sp.,										60–70						s.w.
Verongia hirsuta, Hyatt,		s.w.														
,, *tenuissima*, Hyatt,				400												

IV.—CONCLUDING REMARKS.

With the last lines of the foregoing chapter the direct and immediate task of this memoir is accomplished, but it remains still to summarise its more general deductions with respect to what I regard as its chief purpose. The tendency of this is to clear up the present state of our knowledge, and in the first place to prove that, in spite of the acquirement of many new systematically important characters introduced into descriptive Spongiology by F. E. Schulze, which concern the peculiarities of the internal organisation of the soft parts, all the arrangements of the Keratosa hitherto proposed are, on the whole, far from being natural. I hope I have made it clear that the procedure of subdividing the group either directly into families or preliminarily into suborders may be adopted merely as a measure of provisional character. I hope I have also proved that the genera established in the Keratosa are not homogeneous, the characters distinguishing one part of them being of an absolute, those distinguishing another part of an extremely conditional, and often very ambiguous, nature. I am, finally, far from any illusions, and feel certain that the perusal of the descriptive part of this memoir, as well as of other systematic papers on the Keratosa, must show plainly that in most cases the classifier has to found his species on characters whose stability is quite unknown to him, so that whether they are really of specific importance or fit only for distinction of individuals, remains open to discussion. The reader sees that the state of matters is far from satisfactory; and it is natural to ask whether it admits at least of some conjectures as to the way in which our knowledge of the Keratosa may become more perfect? I believe this question may be answered in the affirmative; but since, in cases where decisive, incontestable proofs are wanting, the probability of the suggestion depends on the number of arguments, I should like, before I pass on to the recapitulation of the grounds favourable to my opinion, to increase their number by an argument of no little consequence. This argument refers to the systematic position of the Keratosa in the whole group of Porifera, and it appears to me that a detailed discussion of this question will be the less superfluous, as the corresponding conclusions promise to be not only of theoretical importance but also of practical applicability. There are mainly in practice two different methods of systematic procedure. The usual one is to begin with lower systematic unities, in order to ascend to families, orders, &c. With respect to many other instances

the matter is quite different, and it depends very often exactly on our conceptions as to whether the given group forms a class or a family whether we subdivide it directly into genera or preliminarily into orders and suborders. Now we have seen that there exist in science quite opposite opinions as to what the genus ought to represent, and that many naturalists find no absolute distinction between genus and species. We have also seen that in the Keratosa, to use the words of Prof. F. E. Schulze,[1] "die Entscheidung der Frage, ob eine Anzahl verwandter Formen als Arten einer Gattung oder als Varietäten einer Art hinzustellen sind, oft besonders schwierig erscheint." Be that as it may, the given forms must be classified and introduced in the system, and the hesitation of the classifier must come to an end. On what now may his final decision depend? That it may depend on the inspiration of the moment is undeniable, but I think the importance of this latter factor must not be exaggerated. Every conscientious investigator will always search for more positive arguments, and it is plain that if he regard the corresponding group as an order subdivisible into families, he will bring his hesitation to an end by creating a new genus; and, on the contrary, if he believe the group to be only a family, he will describe the series of forms in question as a species with varieties. Accordingly, and as I remarked before, from *this* point of view a reliable answer to the question put on the preceding page is the most desirable.

Numerous and very conflicting opinions have been expressed on the problem of the affinities of the horny sponges. I begin with that of Oscar Schmidt. This naturalist does not deny the close relationship of his Ceraospongiæ with the Monactinellida, and namely with Chalinidæ, moreover, he regards them as forming no larger systematic unity than a family; but he considers[2] them to present an independent natural group, and is decidedly against any introduction of true Chalinidæ into it. Hyatt goes still further. He regards the Keratosa as forming an independent order, a very significant statement, since the naturalist just named, when writing that "the characteristics of the order Keratosa are more clearly defined than those of any other among the class Porifera," &c. (Revision, &c., vol. i. p. 399), was of the opinion that the whole group of Porifera form nothing more than a class of Infusoria.[3] There are in his valuable memoir on the North American Porifera no further explanatory observations in this direction, but it is plain that the words above quoted admit of but one explanation, namely, that the Keratosa are to be regarded as a group systematically equivalent to the groups Calcarea and Silicea. Gray[4] and Bowerbank,[5] in harmony with Grant, call the Keratosa also an order, but they class within it the true horny sponges with sponges producing "proper spicules." Finally, Carter,[6] agreeing on the whole with Gray and Bowerbank, differs from them in this point, that he considers the Keratosa to represent two orders, without forming,

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxxii. p. 612.
[2] Spong. d. adriat. Meeres, II. Suppl., p. 9; Spong. d. Küste v. Algier, p. 36.
[3] Revision, &c., vol. ii. p. 481.
[4] *Proc. Zool. Soc. Lond.*, 1867, p. 503.
[5] Monograph Brit. Spong., vol. i. p. 205.
[6] *Ann. and Mag. Nat. Hist.*, ser. 4, vol. xvi., 1875, p. 132.

however, an upper group. This latter statement demands an explanation. The fact is that Carter does not follow the, so to speak, "dendroid" principle of classifying Porifera recommended by Gray; he does not adopt his subdivision of Porifera into two chief groups, that of Calcarea and that of Silicea,[1] but subdivides the whole type or subtype of Porifera into eight equivalent groups (orders), leaving the reader entirely uncertain how the mutual affinities of these eight orders are to be graphically expressed,—whether by eight radial branches from the same spot, or by one chief branch with secondary, tertiary, &c., ramifications. I lay great stress upon this. Our present aims are not only of purely systematic, but also of phylogenetic, character, and the more the most experienced spongiologist of our day, Mr. Carter, has the right to express his opinions on the question, the more one must feel disappointed to find in his system an arrangement which, neglecting the usual laws of the systematic, and yet not accompanied with an explanatory genealogical tree, leaves the reader in the mist of uncertainty as to whether its author regards, *e.g.*, the Calcarea as forming a group systematically equivalent to that, for instance, of Psammonemata, the Ceratina equivalent to the Hexactinellida, &c., or not. Apart from these more general questions, the opinions of Mr. Carter as to the affinities of horny sponges are clear; in harmony with Gray and Bowerbank he composes his third family of Psammonemata (Pseudohircinida) of groups devoid of proper spicules and again of groups provided with them. The opinions of different spongiologists as to the question I am now discussing are thus very contradictory and even conflicting, but although most of them are expressed in very decided language, it would yet be a hopeless task to search into their papers for any grounds in favour of suggestions upheld by them; these grounds are shrouded in darkness. Moreover, the decided language just alluded to is often at variance with other suggestions of the same author. Thus, for instance, with respect to O. Schmidt. On page 36 of his work on the sponges of Algeria he lays stress on his Ceraospongiæ and Chalineæ being quite natural and independent families; on the following page of the same work he says that he feels certain that "gewisse Gattungen einer Chalineæ zu nennenden Familie unter sich weit weniger als mit bestimmten Gattungen der Ceraospongiæ, direct verwandt sind." Under such circumstances there remains no other way of elucidating the matter but to turn to

[1] Dr. Vosmaer (Report on the Sponges dredged by the "Willem Barents," p. 3), agreeing with this proceeding, but not content with the designation of Silicea, since it embraces forms like true Keratosa or Myxospongiæ, *i.e.*, forms devoid of any siliceous spicules, proposes for it the name of "Non-calcarea." I believe this to be scarcely an amelioration. There are indeed cases when negative designations are very fortunate. On the whole, however, they are not to be recommended, and certainly not with respect to the Non-calcarea of Vosmaer. The name of, *e.g.*, *Acrania*, Haeckel, being negative, includes nevertheless a systematically important positive allusion. That of Non-calcarea is devoid of it. I agree that it is illogical to call Silicea *inter alia* sponges without any siliceous spicules, but though illogical this designation is in possession of a phylogenetic sense. As the reader will see later, there can be no doubt as to the fact that Keratosa, like Myxospongiæ (these latter perhaps not directly, but this does not alter the case), owe their origin to siliceous sponges, and from this point of view there can be no objection to the grouping of all these closely allied sponges under the general name "Silicea"—as nobody finds it strange that the order of Diptera includes forms like *Pulex irritans* or the type of Arthropoda animals like *Rhizocephala* or *Tardigrada*.

the actual data, viz., to the differences in structure distinguishing the horny sponges from other Silicea. The usual and natural characteristic of the Keratosa is the following:—Porifera with horny skeleton devoid of proper (siliceous) spicules. This diagnosis alludes to this, that there must exist amongst Silicea, sponges although provided with a true horny skeleton, yet characterised by the possession of spicules produced by the sponge itself. This allusion concerns the groups of Silicea known under the name of Chalinidæ, whose main systematic character consists in the possession of a horny skeleton recalling as to its external structure that of true Keratosa, but rich in horny substance as it is, yet containing within its fibres proper spicules enclosed. Now through the genus *Chalinula*, O. Schmidt, the Chalinidæ are most closely allied to typical Monactinellida. There are accordingly between a typical horny sponge and a typical Monactinellid long series of intermediate connecting stages, and their existence proves that the Keratosa and Monactinellida must have had the same phylogenetic origin. This has never been disputed; and, on the whole, it is in thorough harmony with embryological data also. The larvæ of Keratosa as described by Barrois[1] (*Verongia* [*Aplysilla?*] *rosea*) and F. E. Schulze (*Euspongia officinalis*,[2] *Spongelia pallescens*,[3] *Aplysilla sulphurea*[4]) and those of *Chalinula fertilis* and *Reniera filigrana* as described by Keller[5] and Marshall,[6] as well as their previous and probably further development, admit of no absolute distinctions. Indeed, while the usual mode of division of the ovum is equal, that of the ova of *Chalinula* is, according to Keller, unequal. But, firstly, this difference is of a very subordinate nature, and, secondly, it is still questionable whether this statement of Keller is more reliable than his suggestion as to the sexual dimorphism of the species in question. There can be, I repeat, no doubt as to the Keratosa and Monactinellida having had the same origin. But the matter, indisputable as it is, can be interpreted differently. The genealogical tree accompanying the paper of Prof. Schmidt on the sponges of Algeria (*loc. cit.*, p. 35) shows that this naturalist considers the Keratosa to be an older group than the Monactinellida, to represent, namely, a group from which the true Silicea have originated. If this be true, the systematic proceeding of Hyatt I have spoken of a couple of pages before would receive a thorough sanction, and the class of Non-calcarea, Vosmaer (for in such a case the designation of Silicea applied to the group by Gray would be no longer admissible), would require to be subdivided into two orders, Keratosa and Silicea. This suggestion is, however, far from being reliable, and a short deliberation renders it obvious. I ask what appears more easily and naturally realisable, the transformation of a Siliceous into a Keratose sponge, or *vice versa* of a Keratose sponge into a Monactinellid. I think there can be no doubt as to the answer. In the species *Chalina limbata*, Bk., we have to do with a sponge whose skeletal fibres are extremely poor in proper spicules; an insignificant

[1] *Ann. d. Sci. Nat.* (*Zool.*), sér. 6, t. iii., 1876, p. 56.
[2] *Zeitschr. f. wiss. Zool.*, Bd. xxxii. p. 642.
[3] *Ibid.*, Bd. xxxii. p. 144.
[4] *Ibid.*, Bd. xxx. p. 414.
[5] *Ibid.*, Bd. xxxiii. p. 317.
[6] *Ibid.*, Bd. xxxvii. p. 221.

quantity of them is, however, still to be found. Are these spicules to be regarded as physiologically functional, however it may be? Can we assume that a single row of siliceous spicules render the horny fibres of *Chalina limbata* more hard? Can we ascribe to them any other than phylogenetic significance? Of course not; and, on the other hand, it is also plain that a sudden apparition of spicules in the horny fibres previously devoid of them is thoroughly inexplicable. On the contrary, the substitution of a horny skeleton for a skeleton represented by siliceous spicules is very simply imaginable. In numerous Silicea we have to deal with forms whose siliceous supporting apparatus forms throughout a network in the proper sense of the word. In many other Silicea we meet with forms whose skeleton is represented by spicules lying exclusively isolated; there are again amongst them forms whose skeleton is constituted by spicules aggregated in rows. That a skeleton represented by a compact network is of a firmer build than a skeleton represented by spicules lying isolated is evident. From this point of view it becomes clear that had a sponge once received the faculty of cementing the rows of its spicules with any connecting substance, this acquirement would have proved to be of a great profit to it. It is also equally plain that if the cementing substance proved to be equally hard and steadfast, and at the same time more elastic than the siliceous spicules, it might, in the course of time, have forced away these latter entirely. I hope this theory gives a very simple explanation of the phenomenon. It is also in harmony with the facts concerning the structure of the soft parts of Keratose sponges, and, on the other hand, of Chalinidæ, Renieridæ, &c. Of course the literature of the question is very poor; some remarks of Dr. Vosmaer[1] on the structure of the Renieridæ, as well as a couple of observations on the anatomy of the Chalinidæ by Dr. Keller;[2] the observation of this naturalist[3] on the structure of *Reniera semitubulosa* executed under the influence of Prof. Haeckel's statements on the non-existing racemose type of the canal-system being unreliable; they are, however, quite sufficient for our purposes, and with regard to the Renieridæ I can also make use of my own investigations. As to the Chalinidæ, the drawing by which Dr. Keller illustrates the internal organisation of his *Chalinula fertilis* (*loc. cit.*, pl. xviii. fig. 1) cannot be misinterpreted; the ground-mass being devoid of any granules, and the flagellated chambers of special cameral canaliculi, it is clear that we have here to deal with the type of the canal-system characteristic of Spongelidæ, and the size of the flagellated chambers being, according to Keller (*loc. cit.*, p. 327), 0·02 mm. on an average, and their shape round, with that special modification which distinguishes my genus *Psammoclema*. As to the internal structure of Renieridæ, I differ somewhat from Dr. Vosmaer. Indeed, his remarks are extremely short. He states, however, that their anatomical organisation recalls vividly that of *Euplectella aspergillum*, as

[1] Voorloopig berigt omtrent h. onderzoek aan de Nederl. werktafel in h. Zoöl. Stat. te Napels, Haag (?), 1881.
[2] *Zeitschr. f. wiss. Zool.*, Bd. xxxiii. p. 326.
[3] *Ibid.*, Bd. xxx. p. 579.

described by Prof. F. E. Schulze.[1] Now, so far as the delicate construction of Renieridæ is concerned, I can but confirm Dr. Vosmaer's statements as to the striking resemblance of these Monactinellida with *Euplectella*. Prof. Schulze lays stress, however, also on the fact that in *Euplectella aspergillum*—and as he told me in Hexactinellida in general—the flagellated chambers are comparatively very large, and, in appearance, typically pouch-shaped, recalling the radial tubes of the Syconidæ. In the species of *Reniera* I had for examination, *Reniera aquæductus*, *Reniera filigrana*, *Reniera semitubulosa*, *Reniera fibulata*, and two or three Renieridæ not determined, I found their flagellated chambers to be always of *roundish* outline, therewith not larger, or at least but little larger, than those of, *e.g.*, *Psammoclema vosmaeri*. I would be, however, scarcely right to lay stress on the contradiction in question, for, firstly, it is but too possible that there are representatives of the genus *Reniera* with radial tube-like flagellated chambers, and, secondly, the differences between flagellated chambers of this kind and those characterising my genus *Psammoclema* are of a thoroughly quantitative nature. At any rate, it is clear that, so far as the Monactinellida, the most closely allied to the Keratosa, are concerned, they are characterised by an arrangement of the canal-system of a more primary character than that distinguishing the majority of the Keratosa. Is this not an evident proof that they are to be regarded as palæontologically older sponges?[2] I think all these circumstances together speak so decidedly for the supposition I am now asserting that the matter can be regarded as scientifically proved. This deduction is of great consequence, for under these conditions there are absolutely no grounds for regarding the group of Keratosa as an order, *i.e.*, a systematically higher unity than the families Chalinidæ, Renieridæ, &c., the more so as it is even impossible to say that Keratosa are less closely connected with Chalinidæ than these latter with the Renieridæ. Of course the thorough absence of proper spicules in their skeletal fibres admits of their very sharp diagnosis, while the diagnoses of Chalinidæ and Renieridæ are of a more conditional nature; but who can warrant that the genus *Spongelia* is in closer relationship with *Euspongia* than with *Chalina*? who can guarantee that the relative characters distinguishing *Spongelia* from *Euspongia*, and concerning the internal organisation of the soft parts, are of less importance than the equally quantitative distinctions concerning the properties of the skeleton differentiating the

[1] *Trans. Roy. Soc. Edin.*, vol. xxxix., 1880, p. 661.

[2] The type of canal-system characterised by an entire absence of special cameral canaliculi, and by clearness of the ground-mass surrounding the flagellated chambers, can be regarded as characteristic of Monactinellida in general. Apart from the Renieridæ above mentioned, I can state this with respect to the following forms I had the opportunity of examining—*Suberites domuncula*, N.; *Esperia bauriana*, O. S.; *Myxilla rosacea*, Lbn.; *Myxilla veneta*, O. S.; *Raspailia viminalis*, O. S.; *Acanthella acuta*, O. S.; *Axinella polypoides*, O. S. On the contrary, the canal-system of the representatives of the genus *Papillina*, O. S. (*Papillina suberea*, *Papillina nigricans*), is not less highly developed than that of *Aplysina aërophoba* or *Corticium candelabrum*; but it must be added that the genus *Papillina*, although undoubtedly closely allied to the genus *Suberites*, seems also through the genus *Osculina*, O. S., to be still more closely connected with the Chondrosidæ, and may, together with these latter, represent a family palæontologically not less recent than that of Ceraospongiæ.

Spongelidæ from the Chalinidæ? Indeed, the most simple procedure is to adopt the Keratosa as an independent group; but it should not be overlooked that this procedure is nothing more than the concession to our natural wish to have for the groups we establish the sharpest possible diagnoses.

I should like to summarise my conclusions. We have seen that the subdivision of the Keratosa into two orders is inadmissible; we have seen that their subdivision directly into families gives also as results families of a very ambiguous nature. After the above deduction we can but say that all this is very comprehensible, *since the whole group is nothing more than a simple family.* Of course, as is the case with the subtype of *Acrania*, a high systematic subdivision can be represented by a simple family; and, on the other hand, as is the case with, *e.g.*, Terebellidæ, a family can be subdivided into numerous subfamilies, these latter consisting again of generic unities. This latter measure finds, however, its application in exceptionally rare cases, and only then when it is really necessitated by the richness of the forms as well as by the richness of systematic characters, and, on the other hand, by higher phylogenetic considerations, while the immediate purpose of my foregoing discussion consisted precisely in the attempt to prove that it is due exactly to the erroneous opinion that Keratosa forms a systematically high subdivision, that naturalists split them into orders, suborders, and families. Of course, it cannot be denied that certain genera established in them are more closely connected one with another than with the remaining representatives of the group. This would be, however, only of consequence if all the genera in question were homogeneous, while in reality some of them are undoubted genera, the others perhaps but species. This is the gist of the matter, and I think that the only natural reconciliation of all these contradictions can be obtained by rendering our genera equivalent one to another, which can be realised by enlarging the idea of genus, *e.g.*, by uniting forms, distinguished as *Hippospongia*, *Euspongia*, &c., in the single genus *Spongia*, which would be, on the whole, thoroughly equivalent to the genus *Ianthella* or *Darwinella*. But if the species constituting the conjectural genera *Hippospongia* or *Stelospongos* are yet undoubted species? I answer, prove that they are so, and in that case subdivide the genus *Spongia* into corresponding *subgenera*. As is well known, these latter systematic unities are out of use; I regard, however, their introduction in systematic practice to be equally profitable for systematic purposes in general, as well as with respect to the special case of classifying the Keratosa in a tolerably natural manner. I opened my "criticism of the genera" with a comparison of different opinions as to the value of generic distinctions, and we have seen that in this respect diametrically opposite ideas have been expressed by different naturalists. The word "diametrically" just used alludes to the impossibility of their thorough reconciliation; the introduction of subgenera in zoological calculations would reconcile them at least so far as this is possible, and again it is obvious that sooner or later this reconciliation must be realised, since neither the opinions of Nägeli

nor those of his opponents can be adopted without amendments. As to the suggestion that generic distinctions must be of an absolute character, of course the acquiescence in this demand would place the creation of genera beyond the discretion of classifiers, and thus expel for ever from Science the disputes as to whether this group is to be regarded as a species or as a genus; it is however evident that, strictly and exactly prosecuted, this demand would lead to the most strange and unnatural systematic arrangements. Following it we should be obliged to unite all the Keratosa, with the exception of the genera *Ianthella*, *Darwinella*, and perhaps *Psammopemma* with all Chalinidæ, Renieridæ, perhaps all Monactinellida into a single genus systematically equivalent to that of *Darwinella* or *Ianthella*. For there are no absolute distinctions between *Chalina* or *Reniera* and *Spongelia*, and there are no absolute distinctions between *Spongelia* and *Euspongia* and *Aplysina*, and again there exist such distinctions between most of the Keratosa and Monactinellida on one hand, and *Ianthella*, *Darwinella*, and *Psammopemma* on the other. On the whole, what Prof. Nägeli recommends is applicable only to the palæontologically old groups of plants and animals. But it is not less evident that an unlimited discretion as to the creation of genera would render any systematic progress impossible; to those who feel disinclined to agree with me, I can but recommend an attentive perusal of spongiological systematic literature. The using of a varietal character, as of generic value, conditions the establishment of new apparently highly interesting and deviating species out of forms representing nothing more than by no means instructive varieties, if not individuals of very common species belonging to another genus. It is quite possible that I have myself committed the same mistake, having adopted F. E. Schulze's genus *Hippospongia*, and created a new species *Hippospongia mauritiana*, while this conjectural species is very possibly nothing but a variety or subspecies of *Spongia* (*Euspongia*) *lapidescens*. Both these opinions cannot thus in their entire extension be adopted. In my paper on the Challenger Calcarea an attempt to reconcile them has been made. Whilst subdividing this group into genera I called attention to my intention to execute this task according to the whole of their organisation, by taking into consideration all their organs in their mutual correlation; and with respect to the group just mentioned the carrying out of this principle met no difficulties, and I hope that the genera I have there established are really natural and adoptable. But there are very often cases when such a proceeding is impossible, when large groups of forms differ from one another only in a single character, the conjectural specific distinctions being in one group complete analogues to those in the other. To similar instances the principle I have followed in my above named paper is not applicable, and for my own part I see no other issue but to recommend for such cases the adoption of the scheme of Nägeli, and this in order to protect the establishment of genera so far as possible from the vagaries of classifiers, so that generic unity might serve as a firm basis, which has been wanting in descriptive zoology since the mutability of species was actually proved.

As I remarked before, the realisation of this demand necessitates the introduction of subgenera; and I am the more in favour of this because otherwise I see absolutely no possibility of arranging the Keratosa in a manner not conspicuously artificial, while in the contrary case we should obtain a very natural family of Ceraospongiæ with the following quite homogeneous genera:—*Ianthella*, *Darwinella*, *Simplicella* (with two subgenera *Aplysilla* and *Dendrilla*), *Spongia* (embracing forms classed now in the conjectural genera *Euspongia*, *Hippospongia*, *Cacospongia*, *Stelospongos*, and *Coscinoderma*), *Phyllospongos* (with subgenera *Phyllospongia* and *Carteriospongia*, provided that these subgenera are really in a close relationship), *Spongelia* (with subgenera *Dysidea* and *Psammoclema*), *Psammopemma* (supposing that this conjectural genus be not connected with *Spongelia* by intermediate stages), and *Velaria* (including forms referred at the present time to *Aplysina*, *Verongia*, and *Luffaria*, which may perhaps all be elevated to the rank of subgenera); and it is clear that each of these genera either admits of a very sharp diagnosis or evidences its right to be regarded as a genus by series of characters concerning the whole of the organisation. If now the question be asked, why instead of following, in the descriptive part of this memoir, the scheme just exposed, I have yet followed the arrangement of Dr. Vosmaer, the answer will be because the above scheme only partly decides the problem of a natural arrangement of horny sponges, and I myself am of opinion that when new systems are proposed they must be well established in all their parts. The reader will remember that in the foregoing three chapters we met with a large number of contradictions issuing from the present mode of classifying the Keratosa. The scheme in question reconciles most of them; it does not do so, or at least but partly, with respect to what I called *circulus vitiosus*, characterising the mutual affinities of the genera of the group. This *circulus vitiosus* is striking as concerning the genera belonging to different families; it has, however, equally little right to exist as concerning the mutual relationships of the subgenera. It would have been very easy to proclaim the Keratosa as forming but a single family, and to classify according to this the specimens of the Challenger Collection; but by this proceeding we should not have got rid of difficulties concerning questions of course of a more subordinate nature but nevertheless of vital importance; this proceeding would not have decided the problems as to whether subgeneric value can be really ascribed to the characters distinguishing the *Hippospongiæ* or *Coscinodermata*, &c. This is the second, and the most difficult part of the task, and without the help of Palæontology and Comparative Physiology it will be scarcely decided. As must be evident from the above discussions, by the term "subgeneric character" I understand a character containing in it a new principle of organisation, the corresponding representatives of the group being connected by intermediate stages. That *Euspongia*, *Cacospongia*, *Hippospongia*, &c., present each in their organisation what may be called a new principle is clear; but it is by no means evident whether this, their conjecturally main character, be really constant. Should we feel certain that the fossils described as

horny sponges do really belong to the Keratosa, that, *e.g.*, *Dysidea antiqua*, Carter,[1] from the Carboniferous system, is really a horny sponge and not a worm-tube or something of that kind, in a word, should we feel certain that Keratosa is a palæontologically old group, of course we should regard *Hippospongia*, *Euspongia*, &c., as representing each a subgenus, and pay but little attention to the existence of forms like *Velinea gracilis*, Vosmaer, or my *Cacospongia intermedia* conditioning the *circulus vitiosus* above mentioned. But this is precisely the question to be answered; it is but too possible that Keratosa is a very recent group, and in this case the many-sidedness of their affinities may be explained by their very high variability, in which case only specific and varietal importance must be ascribed to the characters we regard now as of subgeneric or even generic value. Prof. F. E. Schulze established a new genus *Oligoceras;* he told me that all specimens of his *Oligoceras collectrix* were found between stones in a position which renders the presence of a special supporting skeleton superfluous; it is to be asked whether the loss of this latter is immediately realisable or not. It is, in one word, necessary to express more or less approximatively the proportion between the stability of these and other characters and their mutability, *i.e.*, their faculty of conforming to existing influences. His genus *Hippospongia*, F. E. Schulze characterises by the presence of numerous channels, *i.e.*, cavities breaking through the body of its representatives in different directions. That this property is due to the necessity of enlarging the outer surface is perfectly clear; it is again to be asked whether this character can be adopted in a short space of time. Mr. Carter established a genus *Coscinoderma*, but with the diagnosis he gave[2] to it in his last paper the genus is not adoptable: "Sieve-like incrustation, composed of foreign bodies uniformly foraminated and continuously spread over the surface, whose evenness is not disturbed by the usual polygonal projection of the subdermal fibre. Fibre fine, woolly." Should we follow it we should have this genus represented but by the single species *lanuginosum*. I widened the diagnosis and described as *Coscinoderma* also *Coscinoderma altum*, characterised by comparatively thick skeletal fibres, in most cases cored with foreign enclosures. The type-specimen of *Coscinoderma* possesses very fine fibres, all of the same diameter; the skeletal fibres of all *Cacospongiæ* are thick, and usually overloaded with foreign bodies; they admit, however, of the distinction of primary and secondary ones. *Coscinoderma altum* has thick fibres cored with foreign bodies, but all its fibres are of the same size. Ought I to class the form in question in the genus *Coscinoderma* or in that of *Cacospongia?* Ought we to ascribe to the differentiation of the fibres into primary and secondary ones a higher systematic consequence than to their equal size? The reader who has perused my description of the Challenger specimens will find there such alternatives at every step. And to sum up, so long as we possess no statements as to the stability of the characters of the horny sponges we shall have no natural arrangement of them. There

[1] *Ann. and Mag. Nat. Hist.*, ser. 5, vol. i., 1878, p. 139.

[2] *Ibid.*, February 1884, p. 129.

was a time in Zoology when the external shape of the animals was considered quite sufficient for descriptive purposes; this period was followed by the period of, so to speak, anatomical character, naturalists discovered a new source of systematic characters in Comparative Anatomy, and believed its help to be sufficient for deciding the most complicated phylogenetic questions; the apparent success was so great that this conviction finds its echo in papers of very recent date—as for instance in v. Jhering's Monograph on the Mollusca. The time came, however, when zoologists became aware that their anatomical hopes were but illusions, and the word Comparative Embryology became the watchword of the day. That this department of Zoology also has not justified the hopes based upon it is but too well known, and the modern watchword is Comparative Physiology. Whether this study, at the present time in its infancy, will justify what it promises, will be seen later; on the whole, it is clear that in most cases not this alone but all branches of Zoology together will give us the answers we require; but in instances like that concerning the Keratosa, where almost all other lines of research are of no avail, this new science may be particularly welcome. The possibility of a disappointment is of course not excluded, and therefore further purely systematic papers on the Keratosa are of course very desirable. It would be, however, still more desirable that Science, hand in hand with this, would follow up also another way, that, namely, of Comparative Physiology. This is the immediate task to be executed, and in the case of spongiologists residing near the sea-shore it is very easily realisable.

CONTENTS.

PAGE

INTRODUCTION, ... 1, 2

I. ORGANISATION AND CLASSIFICATION OF THE KERATOSA, ... 2–20

Prefatory Remarks, ... 2

Systematic Value of Skeletal Fibres, whether Homogeneous or Heterogeneous, . . . 3

Systematic Value of Skeletal Fibres, whether Cored with or Devoid of Foreign Bodies, . . 9

Systematic Value of the Peculiarity of Skeletal Fibres characteristic of *Ianthella*, . . 11

Systematic Value of the Presence of Filaments, ... 12

Systematic Value of the Properties of the Canal System, ... 16

Corollaries, ... 18

II. CRITICISM OF THE GENERA, ... 21–35

Darwinella, ... 21

Aplysilla, ... 22

Dendrilla, ... 22

Ianthella, ... 22

Velinea, ... 23

Spongelia, Dysidea, Psammascus, ... 23

Psammoclema, ... 25

Psammopemma, ... 25

Euspongia, Hippospongia, Cacospongia, Stelospongos, ... 26

Coscinoderma, ... 28

Phyllospongia, Carteriospongia, ... 29

Oligoceras, Hircinia, Ceratella, ... 29

Luffaria, ... 32

Verongia, ... 34

Aplysina, ... 34

III. DESCRIPTION OF THE SPECIES, ... 37–72

Darwinellidæ,

Ianthella flabelliformis, ... 37

Spongelidæ.

Spongelia spinifera, ... 41

Spongelia pallescens, ... 42

PAGE

Spongelia horrida, ... 42
Psammoclema ramosum, ... 43
Psammoclema vosmaeri, ... 44
Psammoclema foliaceum, ... 45
Psammopemma densum, ... 46
Psammopemma porosum, ... 48

Spongidæ.

Coscinoderma confragosum, ... 50
Coscinoderma denticulatum, ... 51
Coscinoderma altum, ... 52
Euspongia officinalis, var. *lobosa*, ... 53
Hippospongia anomala, ... 54
Hippospongia mauritiana, ... 55
Cacospongia levis, ... 56
Cacospongia amorpha, ... 57
Cacospongia murrayi, ... 57
Cacospongia vesiculifera, ... 58
Cacospongia procumbens, ... 59
Cacospongia dendroides, ... 60
Cacospongia spinifera, ... 61
Cacospongia tuberculata, ... 61
Cacospongia intermedia, ... 62
Cacospongia irregularis, ... 63
Cacospongia oligocéras, ... 63
Cacospongia compacta, ... 64
Cacospongia collectrix, ... 65
Stelospongos longispinus, ... 67
Carteriospongia radiata, ... 67
Carteriospongia otahitica, ... 69

Aplysinidæ.

Luffaria variabilis, ... 69
Verongia hirsuta (?), ... 70
Verongia tenuissima (?), ... 71

BATHYMETRICAL TABLE, ... 73

IV. CONCLUDING REMARKS, ... 75–85
Short Recapitulation of the Deductions of the Foregoing Chapters, ... 75
Affinities of the Keratosa and their place in the General System, ... 76
Definition of the ideas "Genus" and "Subgenus," 81
Scheme of a *Conjecturally* Natural Arrangement of the Keratosa, ... 83
Problems to be Solved in Order to Render an *Undoubtedly* Natural Arrangement of them realisable, 83

PLATE I.

PLATE I.

Ianthella flabelliformis, Pallas; natural size.

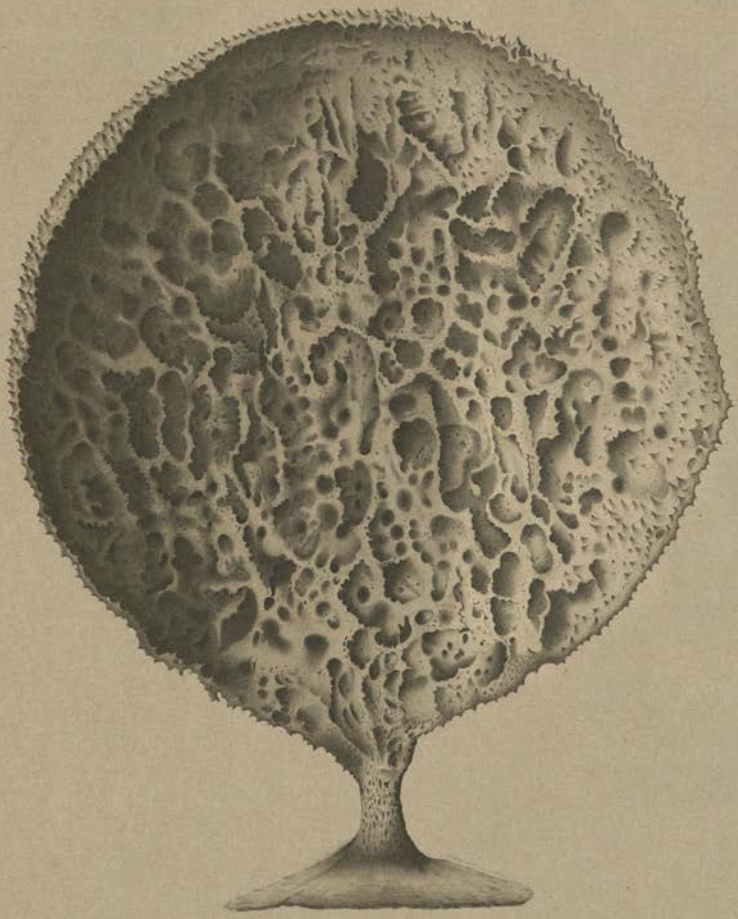


PLATE II.

PLATE II.

Ianthella flabelliformis, Pallas.

Fig. 1. Portion of the outer surface, ... × 6

Fig. 2. Portion of the skeleton of the leaf-like extension; natural size.

Fig. 3. Portion of the skeleton of the stem; natural size.

Fig. 4. Portion of a section showing the arrangement of the canal system, . × 200

Fig. 5. Portion of a section with two flagellated chambers, showing histological elements of the connective tissue,—*Am*, amœboid cells; *St*, stellate and fusiform cells, ... × 600

Fig. 6. Portion of the outer surface (from above) showing the subdermal aggregations of fusiform cells and conjectural gland-cells, . . × 600

Fig. 7. Portion of a longitudinal section through the horny walls of a skeletal fibre, ... × 700

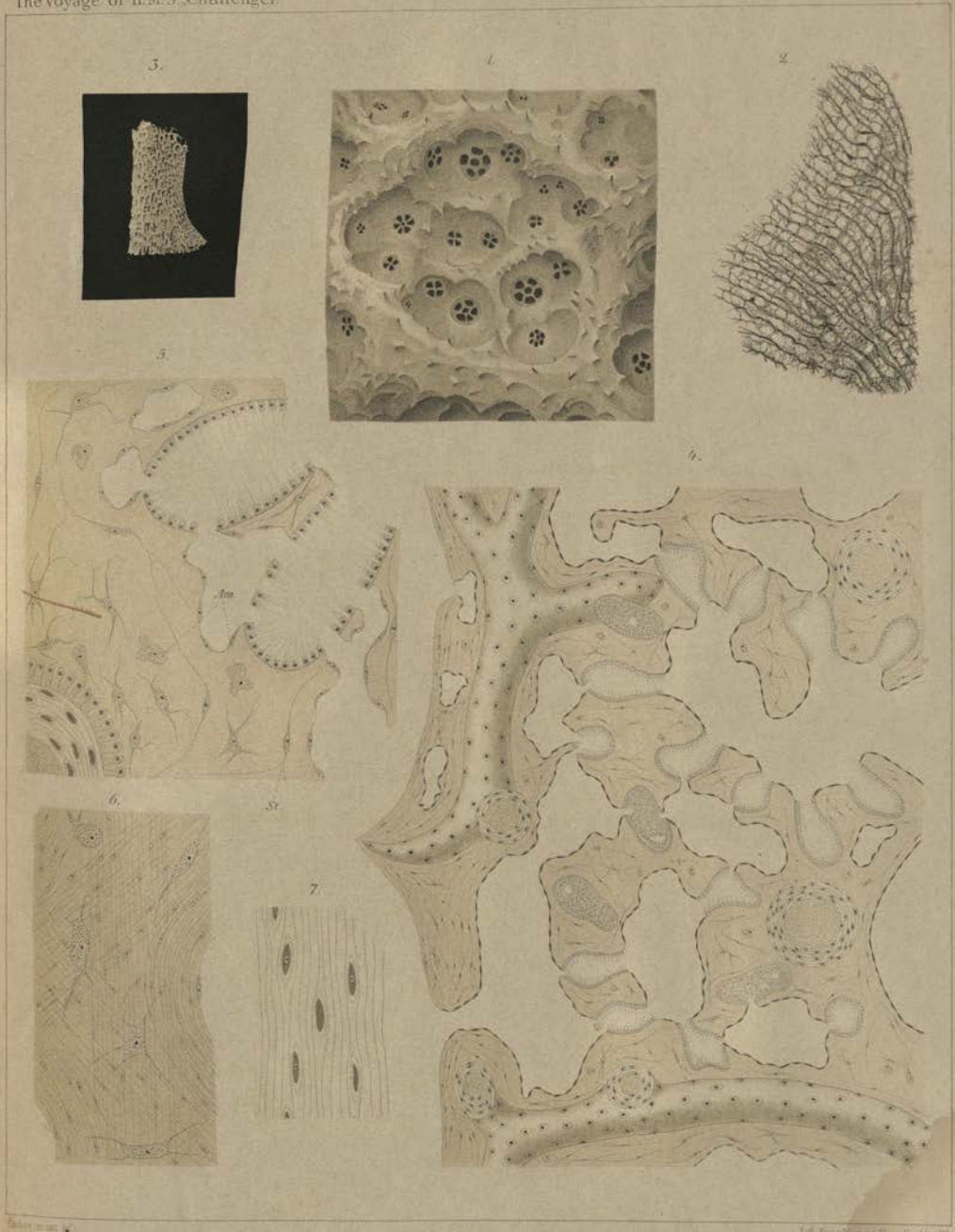


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PLATE III.

PLATE III.

Fig. 1. Portion of the skeleton of *Spongelia pallescens*, O. Schmidt; natural size.

Fig. 2. Skeleton of *Spongelia horrida*, Selenka; natural size.

Fig. 3. Fragment (?) of a specimen of *Psammopemma densum*, Marshall; natural size.

Fig. 4. Portion of a section through its body showing the form and disposition of the flagellated chambers; × 300.

Fig. 5. A colonial specimen of *Psammoclema vosmaeri*, n. sp.; natural size.

Fig. 6. Portion of a section through one of its individuals; × 300.

Fig. 7. Portion of the skeleton of *Psammoclema foliaceum*, n. sp.; natural size.

Fig. 8. The same of *Psammoclema ramosum*, Marshall; natural size.

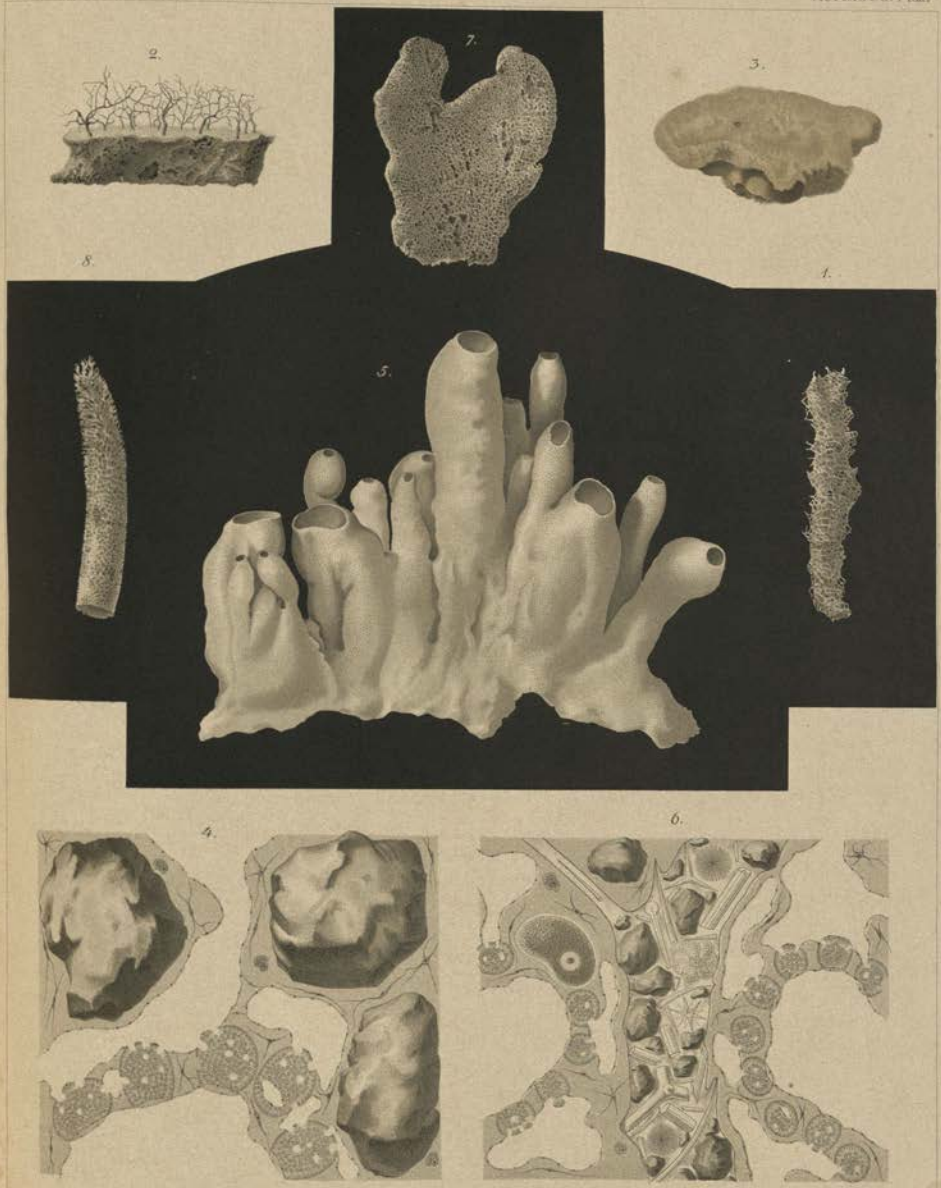

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PLATE IV.

PLATE IV.

Fig. 1. *Psammoclema ramosum*, Marshall; natural size.

Fig. 2. *Cacospongia vesiculifera*, n. sp.; × 2

Fig. 3. *Cacospongia murrayi*, n. sp.; natural size.

Fig. 4. *Carteriospongia otahitica*, Esper; natural size.

Fig. 5. *Carteriospongia radiata*, Hyatt; natural size.

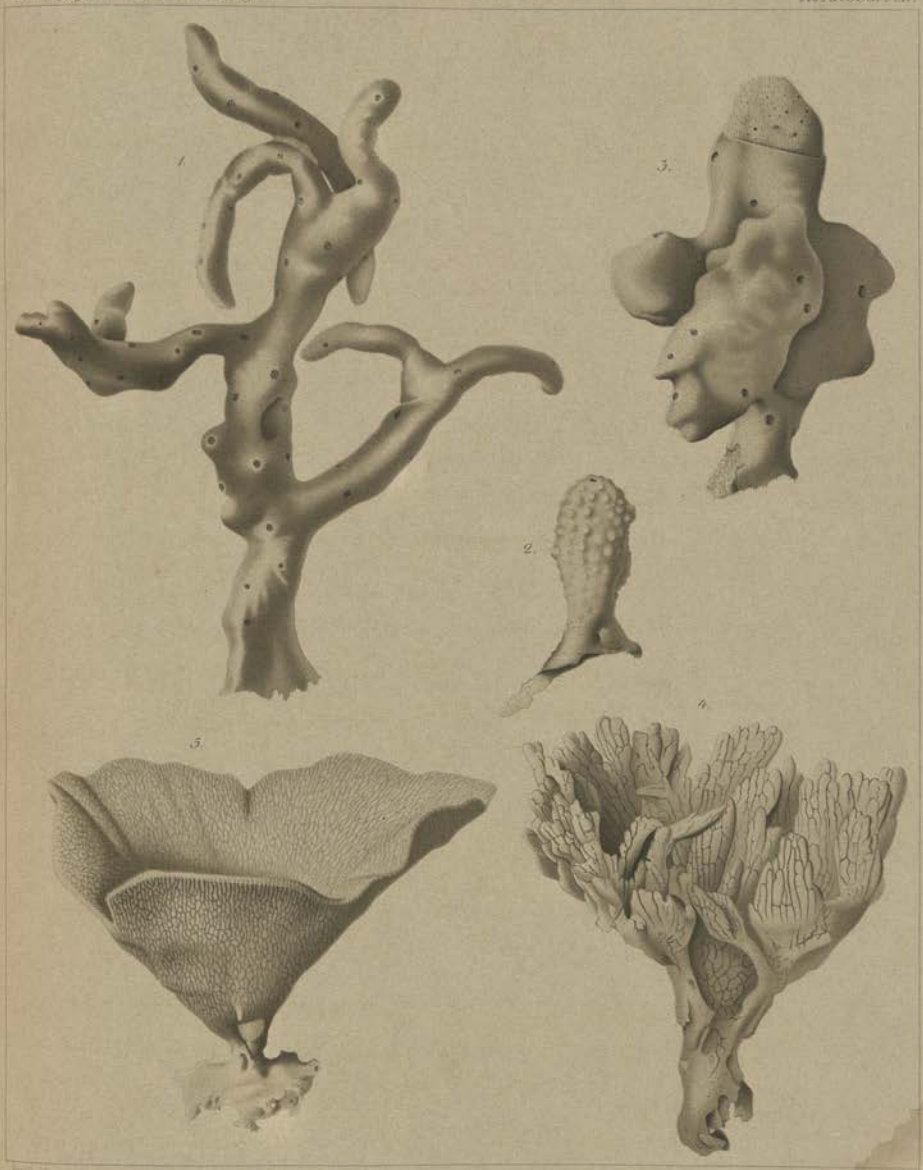

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PLATE V.

PLATE V.

Figs. 1–3. *Cacospongia levis*, n. sp.

Fig. 1. Portion of the skeleton; natural size.

Fig. 2. A longitudinal section through it, ... × 4

Fig. 3. Portion of a section through parenchyma, ... × 300

Figs. 4–6. *Coscinoderma altum*, n. sp.

Fig. 4. Portion of the skeleton; natural size.

Fig. 5. A transverse section of it, ... × 4

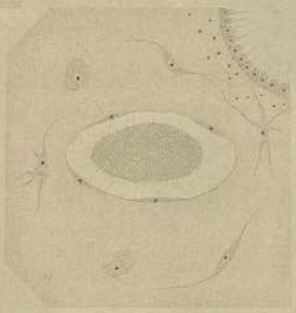
Fig. 6. Portion of a section through parenchyma, ... × 130

Figs. 7–9. *Carteriospongia radiata*, Hyatt.

Fig. 7. A peripheral segment of the skeleton, ... × 4

Fig. 8. Portion of a section through parenchyma, ... × 300

Fig. 9. A sperm-ball and some mesodermic cellular elements, . . × 600



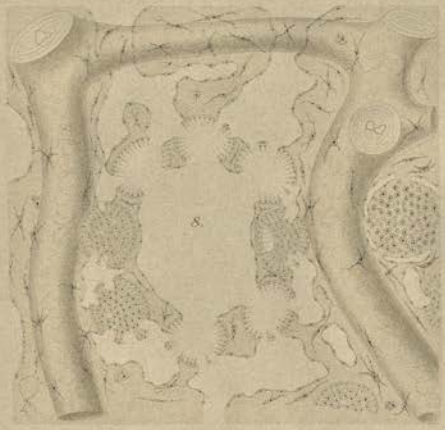


PLATE VI

PLATE VI.

Fig. 1. Portion of the skeleton of *Euspongia officinalis*, var. *lobosa*, nov.; natural size.

Fig. 2. The same of *Hippospongia anomala*, n. sp.; natural size.

Fig. 3. The same of *Hippospongia mauritiana*, Hyatt (*a*, from above; *b*, from the plane of section); natural size.

Fig. 4. The same of *Coscinoderma denticulatum*, n. sp.; × 5.

Fig. 5. The same of *Cacospongia amorpha*, n. sp.; natural size.

Fig. 6. The same of *Cacospongia procumbens*, n. sp.; × 2.

Fig. 7. The same of *Cacospongia intermedia*, n. sp.; natural size.

Fig. 8. The same of *Cacospongia murrayi*, n. sp.; natural size.

Fig. 9. The same of *Cacospongia vesiculifera*, n. sp.; natural size.

Fig. 10. The same of *Cacospongia irregularis*, n. sp.; natural size.

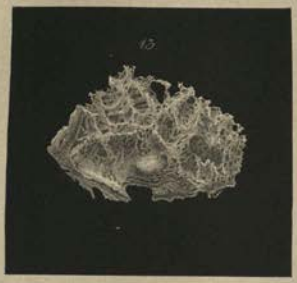
Fig. 11. The same of *Cacospongia compacta*, n. sp.; natural size.

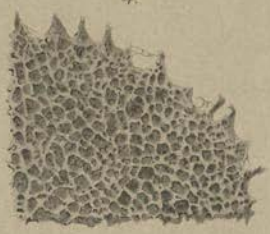
Fig. 12. The same of *Cacospongia spinifera*, n. sp.; natural size.

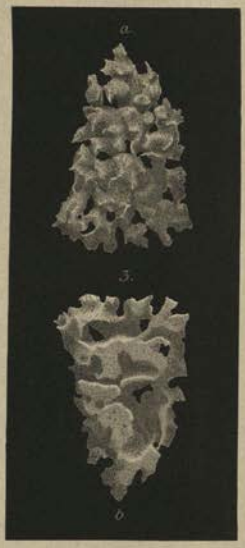
Fig. 13. The same of *Cacospongia oligoceras*, n. sp.; × 2.

Fig. 14. The same of *Cacospongia dendroides*, n. sp.; natural size.

Fig. 15. The same of *Stelospongos longispinus*, Duch. and Mich.; natural size.







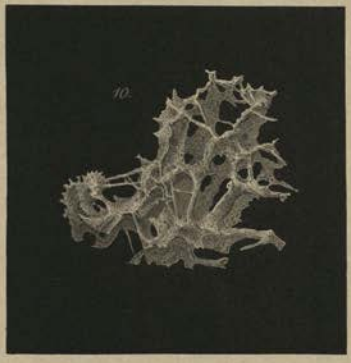


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PLATE VII.

PLATE VII.

Hippospongia anomala, n. sp.; natural size.

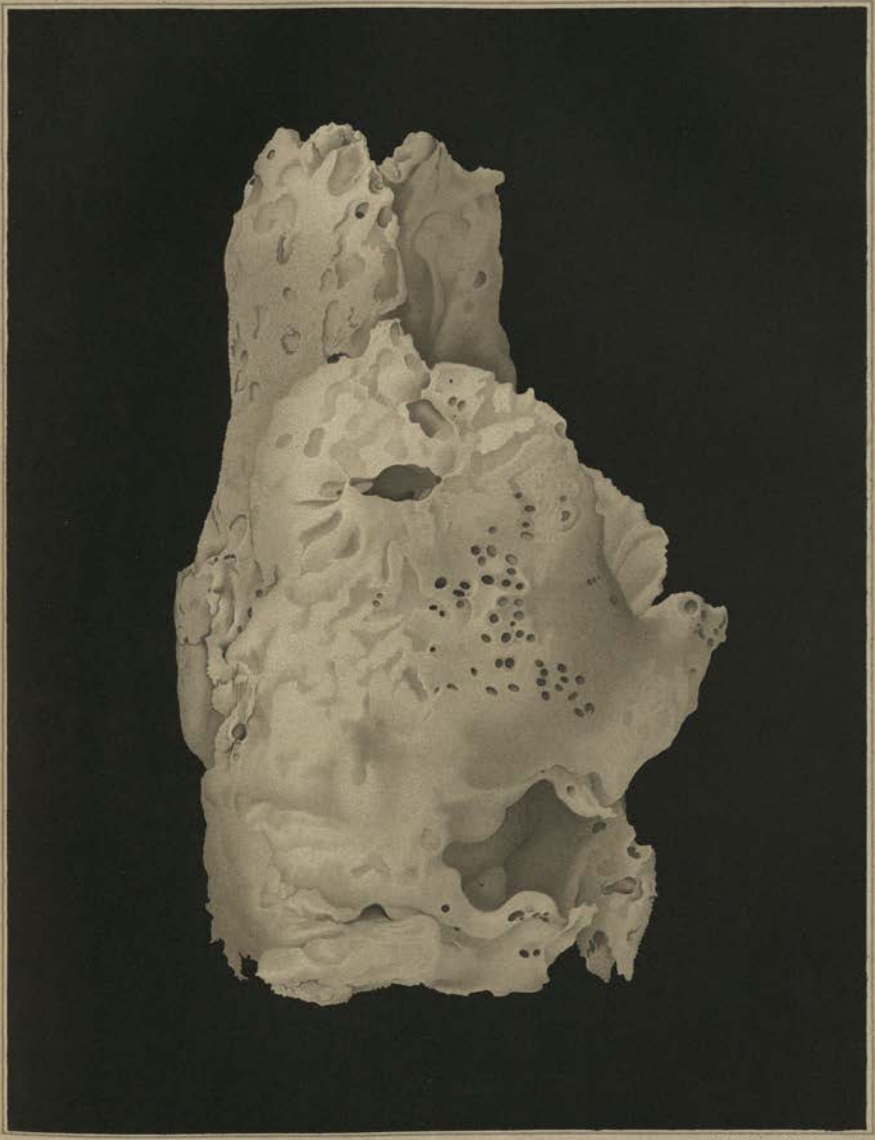

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PLATE VIII.

PLATE VIII.

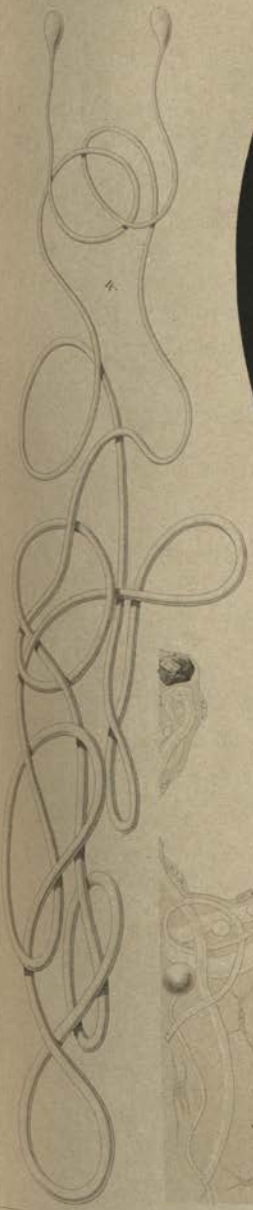
Fig. 1. A specimen of *Cacospongia dendroides*, var. *dura*; natural size.

Fig. 2. Portion of a section through the peripheral part of the body of *Cacospongia dendroides*, var. *friabilis*, showing numerous algoid round bodies and dumb-bell shaped corpuscles, . . . × 700

Fig. 3. A dumb-bell shaped corpuscle; highly magnified.

Fig. 4. A filament of *Stelospongos longispinus*, ... × 400

Fig. 5. A filament of *Cacospongia irregularis*, ... × 400



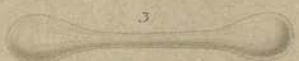


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PLATE IX.

PLATE IX.

Luffaria variabilis, n. sp.

Fig. 1. A colony of three specimens of elongated shape; natural size.

Fig. 2. Portion of the skeleton of one of them; somewhat magnified.

Fig. 3. A specimen of massive shape; natural size.

Fig. 4. A horizontal section through the skeleton of one of its outgrowths; natural size.

Fig. 5. Portion of this latter section; × 14.

Fig. 6. Some of the finest skeletal fibres; × 100.

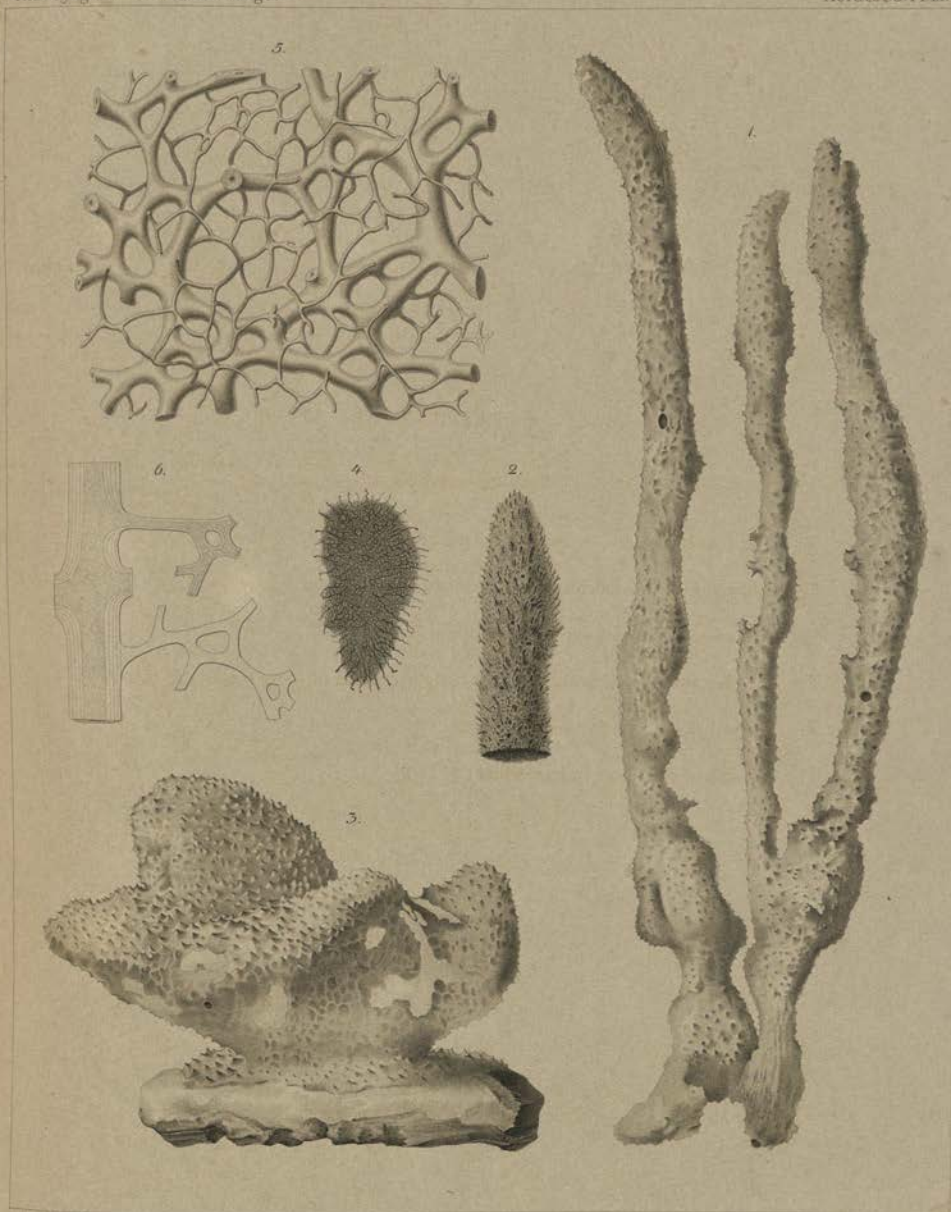

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PLATE X.

PLATE X.

Figs. 1–3. *Verongia hirsuta* (?), Hyatt.

Fig. 1. An entire specimen (the central cavity is opened by means of a longitudinal incision); natural size.

Fig. 2. Portion of its skeleton; natural size.

Fig. 3. Portion of a skeletal fibre, ... × 280

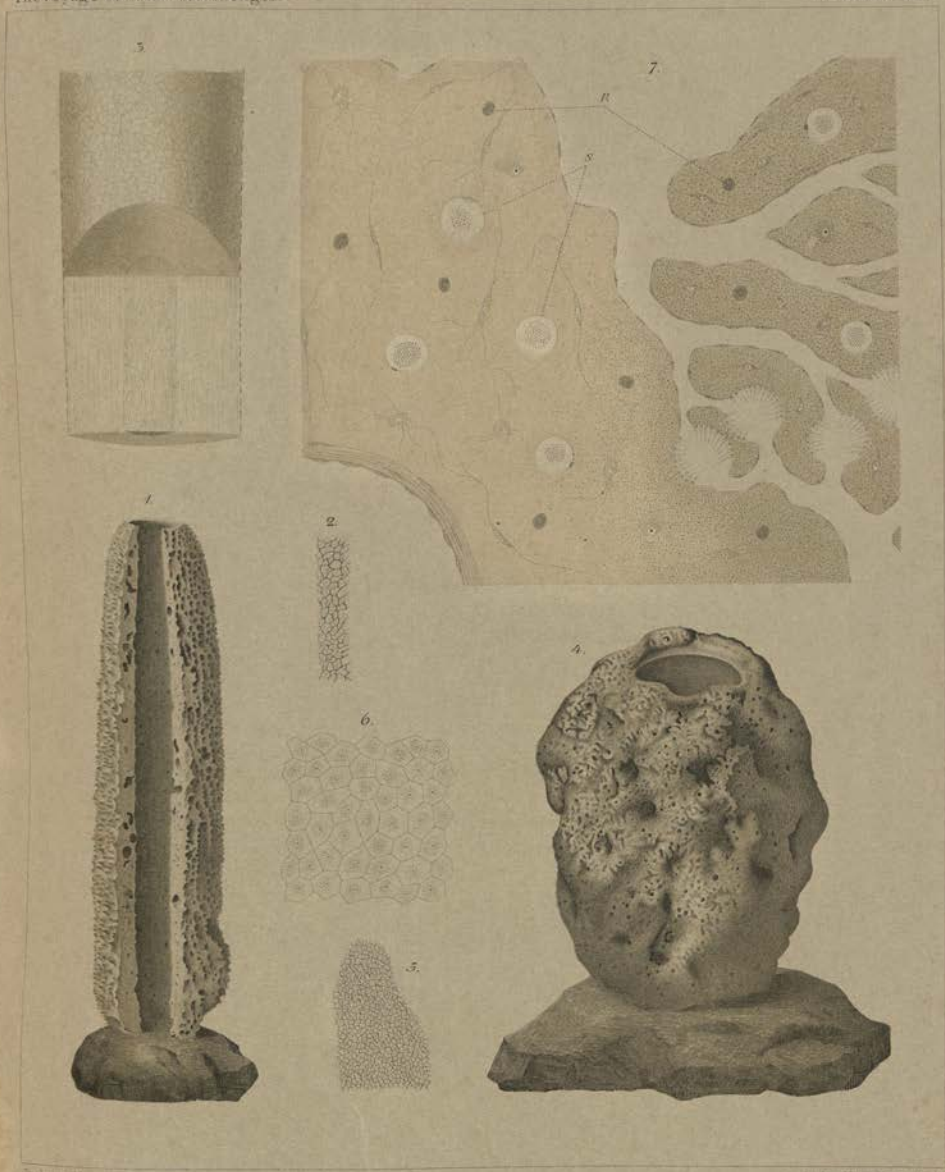
Figs. 4–7. *Verongia tenuissima* (?), Hyatt.

Fig. 4. An entire specimen; natural size.

Fig. 5. Portion of its skeleton; natural size.

Fig. 6. Pavement-epithelium of the outer surface, ... × 240

Fig. 7. Portion of a section through parenchyma, showing the arrangement of the canal system as well as the histological properties of the species,—*S*, spermospores; *R*, "Reservenahrungs-Material" formations of F. E. Schulze, ... × 600



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THE

VOYAGE OF H.M.S. CHALLENGER.

ZOOLOGY.

REPORT upon the CRINOIDEA collected during the Voyage of H.M.S. Challenger during the Years 1873-76. By P. HERBERT CARPENTER, D.Sc., Assistant Master at Eton College.

PART I.—GENERAL MORPHOLOGY, WITH DESCRIPTIONS OF THE STALKED CRINOIDS.

PREFACE.

THE circumstances under which I have come to be charged with the duty of reporting upon the entire collection of Crinoidea made during the Challenger Expedition are as follows.—The researches of my father, Dr. Carpenter, C.B., F.R.S., early led me to take a special interest in *Comatula* and its allies. Some of his statements respecting the anatomy of the arms having been called in question, I was led to reinvestigate the matter towards the end of the year 1875, by methods which were almost unknown during the progress of his researches nearly fifteen years before; and I had the pleasure of verifying all those points in his descriptions of the arms of the European Comatulæ which other observers had disputed. I was then working in the zoological laboratory of Prof. C. Semper at Würzburg, who most kindly placed at my disposal the arms of some tropical Comatulæ which he had obtained in the Philippines. It soon appeared that the minute structure of Crinoids offered a promising field for investigation, and Prof. Semper therefore generously put into my hands several specimens of a remarkable tropical *Actinometra* as material for a monograph of the type. This work occupied me during the whole of the year 1876

and the earlier months of the following year, the greater part of which time was spent at Würzburg, where I had the constant advantage of Prof. Semper's criticism and advice. I also received much valuable help from my father, who freely placed at my disposal all the material which he had accumulated some years before for his investigation of the structure of *Antedon*, *Pentacrinus*, and *Rhizocrinus*. A portion of his observations were communicated to the Royal Society in his now classical memoir on the skeleton of *Antedon rosacea*, and in a later paper on the anatomy of the disk and arms. But he has still a large amount of unpublished material; and of this I have always been permitted to avail myself as fully as I wished. How important this help has been to me will be apparent to every subsequent worker at Crinoid morphology, my own researches having followed very closely on the lines which he had laid down. The results of my study of *Actinometra* and various other Crinoids were communicated to the Linnean Society in the summer of 1877, and shortly afterwards Sir Wyville Thomson offered to entrust me with the preparation of the Report upon the Comatulæ dredged by the Challenger. The collection was sent to me in January 1878; and for the next four years the time which I could spare from my professional duties was devoted pretty continuously to the examination and description of some hundred and fifty new species. Eighteen plates had been drawn and nearly all the specific diagnoses written out, when on Sir Wyville's untimely death in March 1882 I was requested by Mr. John Murray to include the Stalked Crinoids in my Report.

During the cruise of H.M.S. Challenger, and also for some years before it, Sir Wyville had devoted much attention to the Stalked Crinoids, and he proposed himself to investigate the collection of this group of animals which was made during the Expedition. He also arranged with Prof. Alexander Agassiz that he should embody the descriptions of the Stalked Crinoids dredged in the Caribbean Sea by the U.S. Coast Survey steamer "Blake" in his Report on the Challenger collection, so that it might assume the form of a monograph of all the species known to science. He was able to do but little with the "Blake" collection, however; and with the concurrence of Prof. Agassiz it was sent to me by Mr. Murray along with the Challenger collection, proofs of plates, drawings, preparations, and some notes, in the spring of 1882.

Sir Wyville had not made much progress with the preparation of his Report. Twenty-eight plates illustrating the structure of *Holopus* and of the more remarkable types dredged by the Challenger had been drawn and lithographed at Edinburgh under his superintendence by Messrs. George West and W. S. Black, but he was never able to draw up any specific diagnoses; and he left no manuscript behind him of any kind, except one or two generic and specific names which he had written upon the proofs of some of these plates. Descriptions of *Hyocrinus*, *Bathycrinus*, and of *Pentacrinus maclearanus* had, however, already been published in his popular work on the Voyage of the Challenger—The Atlantic.

Upon examining the two collections of the "Blake" and the Challenger, I found that they contained some half dozen species of which no figures had been drawn at all; so that several additional plates would be necessary in order to illustrate them adequately; while diagnoses were wanted of nearly thirty specific types, most of them being undescribed, and some representing new genera.

The preliminary study of these various forms in their zoological aspect alone occupied a good deal of time; but having a strong conviction that they could only be properly understood by the help of a detailed knowledge of their fossil representatives, I was led to take up the study of the fossil Crinoids, more especially those of the Secondary and Tertiary periods. This naturally brought up the question of the relation between the Neocrinoids and the Palæocrinoids, which had already been occupying my thoughts for some time past.

Besides these palæontological questions, many others presented themselves of a morphological nature; and I have endeavoured to obtain such a knowledge of the morphology of recent Crinoids as would be of substantial aid in the interpretation of the many puzzling forms among their fossil representatives, and also bring out their relation to the other Echinodermata. Many others have been at work upon the same lines, with varying opportunities and different degrees of success. Very much, however, still remains to be done, more especially with regard to the finer details of microscopic anatomy, which can only be thoroughly investigated in individuals specially prepared for the purpose when quite fresh. In this way alone is it possible to obtain series of sections of the requisite thinness and perfection of histological detail; and I would therefore ask those who may be disposed to criticise my figures to remember that the preparations were mostly made before the introduction of the Jung or Caldwell microtomes, from material which had been in spirit for periods varying from two to fifteen years.

Several morphological and one or two systematic works upon the Crinoids have appeared during the passage of this Report through the press; and I have therefore added an Appendix which contains a series of notes discussing the various questions to which those works relate. Reference is given to these notes in the text, so that this first part of the Crinoid Report may be regarded as presenting an epitome of our knowledge of Crinoid structure up to the end of the present year.

The second part of the Report, containing descriptions of the Comatulæ collected by the Challenger and "Porcupine," will be published as soon as ever the necessary plates can be drawn, and the manuscript revised, parts of the latter being now more than five years old.

Of the sixty-nine plates accompanying Part I., twenty-eight were drawn at Edinburgh under the direction of Sir Wyville Thomson. Five others illustrating the structure of *Pentacrinus wyville-thomsoni* were prepared by Mr. George West to accompany a memoir upon this type, commenced some years ago by my father, who has

kindly permitted me to make use of them here. They are distinguished by the initials "W. B. C."; while thirty-one of the remaining thirty-six which are marked "P. H. C." have been drawn under my own superintendence by Messrs. C. Berjeau, F.L.S., and P. Highley. I am very greatly indebted to both these gentlemen for the care and skill with which they have performed a difficult and laborious task, one, moreover, involving a considerable acquaintance with minute structural details. I am under similar obligations to Mr. George West, who lithographed three anatomical plates, and also gave me valuable information respecting the specimens from which he had drawn several plates for Sir Wyville Thomson. I have likewise to thank Mr. Black for similar information concerning those plates which had been drawn by himself; and also Mr. W. E. Hoyle, M.A., of the Challenger Office, for kindly working out the magnification of some of the figures upon Mr. Black's plates.

I have further gratefully to acknowledge much valuable bibliographical assistance from my friends Prof. F. J. Bell, F.Z.S., and Mr. W. P. Sladen, F.L.S.; while my thanks are also due to Prof. H. N. Moseley, Dr. P. P. C. Hoek, Mr. H. B. and Dr. G. S. Brady, and to Mr. Edgar Smith, F.Z.S., for kindly identifying various organisms which I had found attached to different parts of the Crinoids.

Prof. Carl Zittel of Munich and Prof. G. Meneghini of Pisa have been good enough to send me several fossil specimens of *Rhizocrinus* for examination, and I take this opportunity of thanking them. But I find it difficult to express my indebtedness to Mr. Charles Wachsmuth of Burlington, Iowa, U.S., who is so well known as the leading authority upon the Palæocrinoidea. Not only has he frequently sent me for examination very rare and valuable specimens illustrating the morphology of the Palæocrinoids and Blastoids, but he has repeatedly answered my inquiries in the fullest and most complete manner possible. The relations of the Neocrinoids and the Palæocrinoids have been the subject of a prolonged discussion between us, extending over more than two years; and it is a matter of sincere regret to me that we have been obliged to agree to differ. Time will show how far our respective views will need modification. We have approached the subject from different sides; but upon one point we are in complete accordance, viz., the desire to find out the truth, whether or not it agree with our own ideas upon the subject. Mr. Wachsmuth will shortly publish an explanation of his own position, to which I would refer those who are interested in the matter.

In conclusion, I must express my sincere thanks to Mr. John Murray and to Prof. Alexander Agassiz for having entrusted me with the working out of the Crinoid collections in their charge, and for their readiness to afford me every possible assistance in doing so; while I would pay a heavy debt of gratitude to the memory of the late Sir Wyville Thomson. It was my privilege to accompany him and my father in the short but eventful cruise of H.M.S. "Lightning" in the year 1868 and in the "Porcupine" expedition of 1869; and to his kindness and encouragement both then and sub-

sequently is due much of such success in zoological work as I may subsequently have attained.

To my father, as will be readily understood, I owe far more than can well be put into words; and I will only express the hope that the following pages may be regarded as a not unworthy sequel to his many contributions to Invertebrate Zoology.

ETON COLLEGE, *December* 1884.

TABLE OF CONTENTS.

MORPHOLOGY.

PAGE

I.—The Skeleton generally, with the Modes of Union of its Component Joints, . . 1
Syzygies, ... 3
Articulations, ... 5

II.—The Stem and its Appendages, ... 12
A. Pentacrinidæ, ... 12
Termination of the Stem below, ... 18
B. Bourgueticrinidæ, ... 23
Morphology of the Stem, ... 28
C. Hyocrinidæ, ... 31

III.—The Calyx, ... 33
A. The Basals, ... 34
B. The Radials, ... 36
C. The Interradials, ... 38
Anal Series, ... 41

IV.—The Rays, ... 47
A. The Ray-Divisions and Arms, ... 47
B. The Pinnules, ... 58
Pinnules of Palæocrinoids, ... 61

V.—The Visceral Mass, ... 67
A. The Oral Plates, ... 70
B. The Perisomatic Skeleton, ... 73
C. The Visceral Skeleton, ... 85

VI.—The Minute Anatomy of the Disk and Arms, ... 88
A. The Geography of the Disk, ... 88
B. The Digestive Tube, ... 88
C. The Water-Vascular System, ... 92
D. The Blood-Vascular System, ... 96
Labial Plexus, ... 97
Plexiform Gland, ... 100
Chambered Organ, ... 106
E. The Genital Glands, ... 108
F. The Nervous System, ... 111
Ambulacral Nerve, ... 112
Axial Cords, ... 114
Parambulacral Network, ... 123
Circular Commissure, ... 125
G. The Sacculi, and the Colouring Matters, ... 127

PAGE

VII.—On the Habits of recent Crinoids, and their Parasites, ... 130
Modes of Attachment, ... 131
Myzostoma, ... 134

VIII.—The Geographical and Bathymetrical Distribution of the Crinoids, . . . 136
A. Geographical Range, ... 136
B. Bathymetrical Range, ... 138
C. The Association of the Genera at Particular Stations, ... 139

IX.—On the Relation between the Recent and the Fossil Neocrinoids, . . . 142

X.—On the Relations of the Neocrinoids to the Palæocrinoids, ... 145
The Müllerian Classification; Articulata and Tessellata, ... 145
General Characters of the Neocrinoids, ... 149
Structure of the Calyx, ... 149
Characters of the Arms, ... 154
The Disk and Oral Plates, ... 155
The Vault of the Palæocrinoids, ... 156
Vault of *Haplocrinus*, *Allagecrinus*, and *Coccocrinus*, ... 157
Vault of *Cyathocrinus*, ... 163
Subtegminal Ambulacra, ... 164
Vault of Actinocrinidæ, ... 167
Homologies of the Calyx and Dome Plates, ... 168
Radial Dome Plates, ... 173
Vault of Platycrinidæ, ... 175
Vault of Ichthyocrinidæ, ... 181
Vault of *Glyptocrinus*, *Reteocrinus*, and *Xenocrinus*, ... 183

XI.—Classification, ... 186
Definition of the Pelmatozoa, ... 186
Definition of the Crinoidea, ... 187
Other Systems of Classification, ... 189
Characters of the Pelmatozoa, ... 193
Definition of the Neocrinoidea, ... 196

XII.—Description of the Specimens, ... 197
Family Holopidæ and Genus *Holopus*, ... 197
A. General Account of the Type, ... 197
Holopus rangi, d'Orbigny, ... 199
The Calyx, ... 199
The Axillary Radials, ... 204
The Arms, ... 206
The Disk and Ambulacra, ... 208
Anatomy of the Arms, ... 209
B. On the Systematic Position of *Holopus*, ... 211
Cyathidium, ... 211
Cotylecrinus, ... 213
Eudesicrinus, ... 214
Gymnocrinus and *Micropocrinus*, ... 216
Edriocrinus, ... 217

PAGE

Family Hyocrinidæ, and Definition of *Hyocrinus*, ... 217
A. General Account of the Type, *Hyocrinus bethellianus*, Wyville Thomson, . . 218
B. On the Systematic Position of *Hyocrinus*, ... 222
Family Bourgueticrinidæ, ... 225
Definition of genus *Bathycrinus*, ... 225
Structure of the Calyx, ... 226
Distribution of the Axial Cords, ... 228
Trifascial Articulations of the Outer Radials and Arm-Joints, . . . 231
The Disk, ... 234
Axial Cords of the Arms, ... 236
Comparison of *Bathycrinus* and *Rhizocrinus*, ... 237
Bathycrinus campbellianus, n. sp., ... 238
aldrichianus, Wyville Thomson, ... 241
gracilis, Wyville Thomson, ... 243
Definition of Genus *Rhizocrinus*, ... 245
Characters of *Conocrinus*, ... 247
Composition of the Calyx in *Rhizocrinus*, ... 248
Views of Pourtalès, Sars, and Ludwig, ... 250
Distribution of the Axial Cords, ... 252
Syzygies in the Arms, ... 254
Affinities of *Rhizocrinus*, ... 255
Rhizocrinus lofotensis, M. Sars, ... 259
rawsoni, Pourtalès, ... 262
Variations in the Shape of the Calyx, ... 264
The genus *Democrinus*, Perrier, ... 268
Definition of the family Pentacrinidæ, ... 270
Synopsis of the Genera, ... 271
Genus *Pentacrinus*, ... 272
A. Characters of the Genus, ... 273
Characters of *Extracrinus*, ... 274
Cenocrinus and *Neocrinus*, ... 279
Cainocrinus, ... 281
Variations in the Size of the Basals in *Pentacrinus*, ... 282
Arms of *Pentacrinus*, ... 284
Characters of the Stem, ... 287
B. On the Characters of Young Pentacrinidæ, ... 289
C. The Calyx and its Contents, ... 291
D. The Geological History of *Pentacrinus*, ... 294
Synopsis of the recent Species, ... 299
Pentacrinus asterius, Linn. sp. 300
milleri, Oersted, ... 306
maclearanus, Wyville Thomson, ... 312
wyville-thomsoni, Jeffreys, ... 313
Termination of the Stem below, and the Mode of Attachment of the Pentacrinidæ, 315
Pentacrinus alternicirrus, n. sp., ... 321
naresianus, n. sp., ... 324
blakei, P. H. Carpenter, ... 328
decorus, Wyville Thomson, ... 330
Variability of its Characters, ... 335
Pentacrinus mollis, n. sp., ... 338

PAGE

Definition of genus *Metacrinus*, ... 339
Synopsis of the Species, ... 344
Metacrinus angulatus, n. sp., ... 345
cingulatus, n. sp., ... 347
murrayi, n. sp., ... 349
nobilis, n. sp., ... 351
varians, n. sp., ... 353
moseleyi, n. sp., ... 355
wyvillii, n. sp., ... 358
costatus, n. sp., ... 360
nodosus, n. sp., ... 364
interruptus, n. sp., ... 367
tuberosus, n. sp., ... 369
Family Comatulidæ, and Definition of genus *Thaumatocrinus*, ... 370
Thaumatocrinus renovatus, P. H. Carpenter, ... 372

XIII.—Bathymetrical Distribution and Station Lists, ... 374
Station List of the Stalked Crinoids which have been obtained by the various British Expeditions for Deep-Sea Exploration between the Years 1868 and 1880, . . 374
Station List of the Stalked Crinoids which have been obtained by the various American Expeditions for Deep-Sea Exploration (mostly under the direction of Mr. Alexander Agassiz) between the Years 1867 and 1880, ... 379
A List of the known Living Species of Stalked Crinoids, showing their Bathymetrical and Geographical Distribution, ... 385
Analysis of this List, ... 388
Bathymetrical Tables, ... 388
Summary, ... 390
Crinoids of the Abyssal Zone, ... 391

APPENDIX.

PAGE

Note A.—On the Homologies of the Crinoidal Calyx in the other Echinoderms, . . . 393
Apical System of Urchins and Starfishes, ... 393
Origin of the Odontophores of Starfishes, ... 398
The Mutual Relations of Crinoids, Asterids, and Echinids, ... 400
Note B.—On the Basals of Fossil Comatulæ, ... 402
Note C.—On the Excentric Position of the Mouth in *Actinometra*, ... 403
Note D.—On the Supposed Communication of the Chambered Organ and Labial Plexus with the Exterior, 404
Note E.—On the Intervisceral Blood-Vessels, ... 405
Note F.—On the Relation of the Vascular Systems of a Crinoid to those of the other Echinoderms, . 405
Note G.—The Nervous System of the Crinoidea, ... 407
The Nervous Nature of the Axial Cords, ... 407
Their Morphology and Development, ... 410
Nervous System of the Blastoids, ... 413
The third Nervous System of Jickeli, ... 415

Bibliography of the Neocrinoidea, ... 417

Index to Authors quoted, ... 429

General Index, ... 431

Explanation of the Plates, ... 441

INDEX TO WOODCUTS.

PAGE

Fig. 1. Calyx of *Promachocrinus kerguelensis*, ... 37

Fig. 2. Diagram showing the course of the Digestive Tube in an endocyclic Crinoid (*Antedon*, *Pentacrinus*, &c.), as seen from the ventral side, ... 89

Fig. 3. Diagram showing the course of the Digestive Tube in an *Actinometra* with Interradial Mouth, as seen from the ventral side, ... 92

Fig. 4. Diagrammatic transverse section of an ungrooved ovarian pinnule of *Actinometra parvicirra*, . 113

Fig. 5. Diagrammatic transverse section through the end of a grooved pinnule of *Actinometra parvicirra*, ... 121

Fig. 6. Longitudinal section of a pinnule joint of *Actinometra nigra*, ... 121

Fig. 7. Longitudinal section of the ventral perisome in a pinnule of *Actinometra nigra*, . . 122

Fig. 8. Diagrammatic transverse section of an ambulacrum on the disk of *Antedon eschrichti*, . . 123

Fig. 9. Interradial plates of *Apiocrinus roissyanus*, ... 183

Fig. 10. View of the upper part of the calyx-tube of *Holopus rangi*, on its lower or bivial side, . . 203

Fig. 11. Diagram of a horizontal section through the lowest portion of the basal ring of *Bathycrinus aldrichianus*, ... 226

Fig. 12. Diagram of a horizontal section through the calyx of *Bathycrinus aldrichianus* at the level of the upper part of the basiradial suture, ... 228

Fig. 13. Diagrammatic vertical section through the calyx of *Bathycrinus aldrichianus*, . . . 229

Fig. 14. Plan of the distribution of the axial cords in the calyx of *Bathycrinus aldrichianus*, . . 229

Fig. 15. *Bathycrinus campbellianus*, n. sp., ... 239

Fig. 16. *Bathycrinus gracilis*, Wyville Thomson, ... 244

Fig. 17. Diagrammatic vertical section through the calyx and disk of *Rhizocrinus lofotensis*, . . 251

Fig. 18. Diagram of the distribution of the axial cords in the calyx of *Rhizocrinus lofotensis*, . . 253

Fig. 19. The calyx and arm-bases of two specimens of *Rhizocrinus rawsoni* from Panama, . . 267

Fig. 20. Diagram showing the arrangement of the axial cords in the calyx of a *Pentremites*, supposing it to be the same as in the calyx of a Crinoid, ... 413

Fig. 21. *Tiarechinus princeps*, Laube, inverted so as to show the resemblance of its apical system to the calyx of a Crinoid, ... 414

INDEX TO THE TABULAR STATEMETNS IN CHAPTERS I.-X.

PAGE

TABLE I.—Water-pores of *Hyocrinus*, ... 95

TABLE II.—Showing the Geographical and Bathymetrical Range of all the Genera of Recent Crinoids, 137

TABLE III.—Showing the Frequency of Occurrence of all the Genera of Recent Crinoids at depths below 250 fathoms, ... 138

TABLE IV.—Showing the number of times that Isolated Species of Stalked Crinoids have been dredged, 139

TABLE V.—Showing the Association of Crinoid Genera at different Stations occupied by the "Porcupine," Challenger, and "Talisman," together with the number of Species obtained at each Station, . 140

TABLE VI.—Showing the Association of Crinoid Genera in the Caribbean Sea, together with the number of times that two or more Species of *Pentacrinus* were found at the same Station, . . . 141

TABLE VII.—Showing the Mutual Homologies of the Principal Plates in the Actinal and Abactinal Systems of Echinodermata, ... 169

MORPHOLOGY.

I.—THE SKELETON GENERALLY, WITH THE MODES OF UNION OF ITS COMPONENT JOINTS.

The organisation of a Crinoid is broadly divisible into two well-marked portions, to which the general names ambulacral and antiambulacral may be given. They correspond, on the whole, to the left and right larval antimers respectively, though probably not exactly so. The first is the visceral mass or "disk," in which is situated the whole of the digestive tube, with both its terminal openings. It likewise contains the central ends of the radial water-vessels and blood-vessels, which converge towards their respective circum-oral rings, and also the corresponding portions of the ambulacral nervous system (Pl. LXII.).

Both the disk and its extensions in the perisome clothing the ventral surface of the arms and pinnules are usually more or less covered by calcareous plates, the arrangement of which will be described subsequently (Pl. VI. fig. 4; Pl. XVII. figs. 6–10; Pl. XXVI. figs. 1, 2; Pl. XXXIII. figs. 6, 7; Pl. XXXIX. fig. 2; Pl. XLI. figs. 4, 12–14; Pl. XLIII. fig. 3; Pl. XLVII. figs. 10–13; Pl. L. fig. 2; Pls. LIV., LV.). They represent a portion of that element of the Crinoid skeleton to which the name "perisomatic" was given by Sir Wyville Thomson[1]; for they are all originally developed from simple cribriform films of limestone, such as appear in all young Echinoderms, and thicken by continual repetition of the same formation.

The antiambulacral portion of a Crinoid consists of the stem and its appendages, the calyx, and the skeleton of the rays, arms, and pinnules. This constitutes the radial skeleton, as the term is understood by Dr. Carpenter,[2] viz., that which is perforated by a central canal lodging an extension of the fibrillar envelope around the chambered organ (Pl. VIIb. fig. 2; Pl. XXIV. figs. 2–6, *ca*; figs. 7–9, *ar*; Pl. LVIII. figs. 1–3, *ar*; Pl. LXII.).

Sir Wyville Thomson was unaware that the primary interradial cords proceeding from the chambered organ perforate the basal plates (Pl. VIIb. fig. 2; Pl. XXIV. fig. 7;

[1] On the Embryogeny of Antedon rosaceus, Linck, *Phil. Trans.*, 1865, pp. 540, 541.

[2] Researches on the Structure, Physiology, and Development of Antedon rosaceus, part i., *Phil. Trans.*, 1866, p. 742.

Pl. LVIII. figs. 1, 3—*ai*; Pl. LXII.); and he therefore considered them as belonging to the perisomatic system, on the ground of their not being thickened by the peculiar fasciculated tissue of parallel rods such as is found in the growing stem- and arm-joints. He described this fasciculated tissue as appearing in the first radials. But according to Dr. Carpenter "there is no distinction in texture between the endogenous additions by which the first radials and the basals are respectively thickened; so that we cannot place them in separate categories on this score. But further, we have seen that in the stage now described, the basals as well as the radials are perforated to give passage to the radiating extensions of the sarcodic axis of the stem, which only reach the radials through the basals; so that this ground of distinction also fails to separate them."

The basals and radials form part of the apical or abactinal system of the Crinoid, and are represented by the genital and ocular plates of the Urchins, and their homologues in the other Echinoderms.[1] The oral plates of the Crinoid correspond in like manner with the mouth-shields of Ophiurids, the "odontophores" of Asterids, the oral plates of the Psolidæ, and possibly also with the five actinal plates of *Palæostoma mirabilis* among the Urchins.[2] As regards the rest of the Crinoid skeleton, however, nothing more than a very general homology can be established with the skeleton of the other Echinoderms.

The perisomatic skeleton consists essentially of numerous minute plates which are usually more or less isolated, but sometimes slightly connected by fibrils of connective tissue (Pl. VI. fig. 4; Pl. XVII. figs. 6–10; Pl. XXVI. figs. 1, 2; Pl. XXXIII. figs. 6, 7; Pl. XLI. figs. 4, 12–14; Pl. XLIII. fig. 3; Pl. XLVII. figs. 10–13; Pl. L. figs. 1, 2; Pls. LIV., LV.; Pl. LVII. fig. 3, *an*; Pl. LXII.). The radial skeleton, however, consists of successive joints and rods which are developed in a longitudinal direction, and are united to one another by articulation or suture. In either case the ultimate union of the two joints is effected by means of connective tissue fibres, which pass from the nucleated and pigmented organic basis of the one joint into that of the other (Pl. VIIb. figs. 1, 8, *li*, *ld*. Pl. XXIV. figs. 6, 7; Pl. LVIII. figs. 1–3—*l*, *lb*, *L*). These fibres are sometimes quite short, and their ends are surrounded by the denser layers of calcareous reticulation on the apposed surfaces of the two joints, which are thus closely and immovably fitted together, though they can be separated by the action of alkalies. This mode of union is called a "suture," or better, a "synostosis."[3]

The first radials of the Comatulæ are connected in this manner both with one another and with the centro-dorsal. The same mode of union also occurs between the radials of the Pentacrinidæ and the basals on which they rest, as well as between the five individual

[1] On the Oral and Apical Systems of the Echinoderms, part i., *Quart. Journ. Micr. Sci.*, vol. xviii., N. S., pp. 367–382. Some disputed points in Echinoderm Morphology, *Ibid.*, vol. xx. pp. 322–329. On the Apical System of the Ophiurids, *Ibid.*, vol. xxiv. pp. 1–22. *Vide*, Note A.

[2] Oral and Apical Systems, part ii., *Ibid.*, vol. xix., N. S., pp. 191–193.

[3] See Simroth, *Zeitschr. f. wiss. Zool.*, Bd. xxvii. p. 435; and also P. H. Carpenter, On the genus Actinometra, with a morphological account of a new species from the Philippine Islands, *Trans. Linn. Soc. Lond.* (Zool.), ser. 2, vol. ii. pp. 55, 56, pl. iii. fig. 4.

plates which make up each of these rings (Pl. XII. figs. 1, 2, 11–16, 22–25; Pl. XVIII. figs. 4–7; Pl. XX. figs. 1–3, 6–9; Pl. XXI. figs. 6, 7; Pl. XXIV. fig. 6, *lb*; fig. 7, *l*, *lb*, *L*; Pl. LVIII. fig. 1, *l*, *lb*; fig. 2, *L*). The radials of *Bathycrinus* are likewise united in this way (Pl. VIIb. fig. 4, *l*); but the sutures between the basals seem to be of a still closer nature. They are visible externally in young individuals but disappear in the adult, so that the "base" seems externally to consist of but one single piece[1] (Pl. VIIa. figs. 12–14). Sections through a decalcified specimen show, however, that it is really composed of five parts like the base of *Pentacrinus* (Pl. VIIb. fig. 2, *B*). These five parts are, nevertheless, very closely anchylosed. No parallel fibres of connective tissue pass between them, such as unite the five first radials together (Pl. VIIb. fig. 4, *l*). But the organic basis of the skeleton is much less close, if not absent altogether, along five lines which radiate outwards from the chambered organ and indicate the position of the sutures. They stain less deeply with hæmatoxylin than the surrounding tissue, but do not reach the exterior of the section (Pl. VIIb. fig. 2). Neither are they visible in sections through the top and bottom of the basal piece; and but for the knowledge obtained in this way, the basal piece would probably have been described as an uppermost stem-joint, as has actually happened in the case of *Rhizocrinus*.

In some individuals of *Rhizocrinus lofotensis* (Pl. IX. figs. 1, 2) there are no indications of suture, even in the adult; though in others the sutures are visible externally (Pl. X. fig. 2). In the former case the nuclear connective tissue network is continuous through the whole section, which exhibits no unstained radiating lines, as do similar sections of *Bathycrinus*. There is a marked difference between the two genera, however, as regards the lateral union of the radials. Those of *Bathycrinus* are united by synosteal fibres (Pl. VIIb. fig. 4, *l*), just as in *Pentacrinus* (Pl. XXIV. figs. 7–9; Pl. LVIII. fig. 2, *L*) and *Comatula*. But those of *Rhizocrinus* are much more closely connected, just in fact in the same way as the basals of *Bathycrinus* are. No ligamentous fibres are visible in horizontal section, but only five (or six) radiating lines where the nuclear network is incomplete (Pl. VIIIa. fig. 6). The radials in this type, and the basals in *Bathycrinus*, seem to be united by a limestone deposit which has different characters from that usually found in Echinoderms; and I think it will be advantageous to denote this by the term "anchylosis," reserving "synostosis" for cases in which ligamentous fibres are concerned in the union of the joints; though both of them, like the "syzygy," would be considered as sutures.

Smooth sutural unions like those between the basals and radials, though somewhat less close in their character, occur at intervals in the stem of the Pentacrinidæ, every nodal or cirrus-bearing joint being united in this way to the joint below it (Pl. XIX. figs. 3, 4; Pl. XXII. figs. 16, 20, 21; Pl. XXVI. figs. 12–16; Pl. XXXI. fig. 3;

[1] This must be carefully distinguished from the "article basal" of the Apiocrinidæ, which is the uppermost stem-joint that supports the basals.

Pl. XXXII. figs. 1, 2; Pl. XXXVII. figs. 5–8, 19, 21; Pl. XXXIX. figs. 3, 5, 6; Pl. XLI. figs. 5, 15; Pl. XLV. figs. 3, 5, 6; Pl. XLVII. figs. 1–3; Pl. L. figs. 4, 20, 21; Pl. LI. figs. 5–8).

The external line of separation frequently disappears altogether, or is only traceable with great difficulty, and the two joints, primitively separate, become practically fused into one (Pl. XLII. fig. 1; Pl. L. fig. 3). I cannot find any mention of this peculiarity in the classical memoir of Johannes Müller,[1] who spoke of the successive unions of the stem-joints indifferently as "Näthe oder Gelenke." So far as I can make out, it was first noticed by Sir Wyville Thomson in *Pentacrinus decorus*;[2] and Lütken[3] subsequently described it in more detail in *Pentacrinus asteria* and *Pentacrinus mülleri*. Quenstedt[4] also noticed it in the fossil species *Pentacrinus scalaris* and *Pentacrinus jurensis*.

An essentially similar mode of union between certain of the arm-joints was spoken of by Müller as a "syzygy," and described as an immovable sutural union. The name syzygy has since been applied to the sutural union of the nodal stem-joints with those next below them; and Müller's terms "hypozygal" and "epizygal" for the two arm-joints which are united by syzygy (Pl. XII. figs. 7, 10, 18, 21; Pl. XXXa. figs. 9, 10, 12; Pl. XXXII. figs. 4, 9, 15, 18) may be conveniently applied in the case of the stem-joints also.

In all the recent Comatulæ the apposed faces of the two portions of a syzygial joint are marked by a series of slightly elevated ridges with alternating furrows, which radiate from the opening of the central canal towards the dorsal margin of the joint. In *Actinometra typica* these ridges are frequently not perfectly continuous; but they are broken up into a row of little elevations, squarish or oblong in shape, and arranged with their longer axes radiating outwards from the central canal. On some joints these are not very numerous, and as their terminal faces are marked by median vertical lines, they have been wrongly described as surfaces effecting a ligamentous articulation of the bifascial type, such as will be described immediately.[5]

The radiating arrangement is usually much less marked in the Pentacrinidæ than in the Comatulæ, the striation being frequently only visible at the extreme marginal portions of the syzygial surfaces (Pl. XII. figs. 7, 10, 18, 21; Pl. XXI. figs. 1*d*, 2*d*, 5*a*; Pl. XXX. figs. 20, 21) as figured by Müller in *Pentacrinus asteria*,[6] while in some cases it appears to be absent altogether, the apposed faces being perfectly smooth

[1] Ueber den Bau des Pentacrinus caput-Medusæ, *Abhandl. d. k. Akad. d. Wiss. Berlin*, 1843.

[2] Sea Lilies, *The Intellectual Observer*, No. 31, August 1864, p. 7.

[3] Om Vestindiens Pentacriner, med nogle Bemaerkninger om Pentacriner og Söliljer i Almindelighed, *Vidensk. Meddel. f. d. nat. Foren. i Kjøbenhavn*, 1864, Nos. 13–16, pp. 198, 199.

[4] Petrefactenkunde Deutschlands, Bd. iv., Asteriden und Encriniden, pp. 196, 230, Taf. 98, figs. 2, 3, 107.

[5] See Lovén, Phanogenia, ett hittills okändt slägte af fria Crinoideer, *Öfversigt k. Vetensk.-Akad. Förhandl.*, Årg. xxiii., No. 9, p. 230, fig. *c*; and also P. H. Carpenter, The Comatulæ of the Leyden Museum, *Notes from the Leyden Museum*, vol. iii. pp. 197–199.

[6] *Op. cit.*, Taf. ii. fig. 4.

(Pl. XXVI. figs. 5, 8; Pl. XXXVII. figs. 3, 4; Pl. L. figs. 6, 7, 12, 13) like the apposed surfaces of the radials and basals respectively (Pl. XX. figs. 2, 3, 6, 9). This is also the case in *Rhizocrinus*, which presents another peculiarity as well. Near the dorsal edge of the upper face of the hypozygal there is a more or less well-marked pit (Pl. X. figs. 1, 6, 8, 18), and a corresponding peg-like process projects from the under face of the epizygal (Pl. X. figs. 17, 19), so that closeness of union is effected in this way instead of by the usual radiating ridges.

Another arrangement which effects a somewhat closer syzygial union than usual, presents itself in the arms of *Pentacrinus naresianus* (Pl. XXX. figs. 20, 21, 23; Pl. XXXa. figs. 9, 10, 12) and of *Pentacrinus blakei* (Pl. XXXII. figs. 4, 5, 7, 9, 12, 14). The apposed surfaces are not flat or slightly curved, but the proximal face of the epizygal rises to a sharp crest which is interrupted by the central canal, and fits into a corresponding re-entering angle on the distal face of the hypozygal, so that the two joints interlock very closely. This peculiarity is very apparent in a side view of the arm (Pl. XXX. fig. 23); but when seen from the dorsal side, the distal edge of the hypozygal appears to be very convex and to project strongly forward into the epizygal (Pl. XXX. fig. 1; Pl. XXXI. fig. 2).

Very different modes of articulation occur in the Crinoid skeleton, so that the amount of play between two successive joints varies considerably. It is probably at a minimum in the stem of *Hyocrinus* (Pl. VI. fig. 2). We do not know the nature of the basal part of the stem; but the lower joints of the fragment, 170 mm. in length, which was obtained, are cylindrical, with their terminal faces devoid of any fossæ, but marked by a radiating pattern of grooves and ridges. This, however, is sometimes absent, as shown in Pl. Vc. fig. 4. Sir Wyville Thomson spoke of the joints as united by a close syzygial suture;[1] but the ligamentous fibres which effect their union (Pl. Vc. fig. 5, *ls*) are longer than I have ever seen them in any real syzygy, and rather resemble those which unite the successive pinnule joints of other Crinoids when muscles are absent. They are all of the same length and not longer in the centre than at the periphery, as they are between the deeply hollowed stem-joints of the Bourgueticrinidæ (Pl. VIIa. figs. 8–11; Pl. X. figs. 11–14). But I should hardly describe this mode of union as a syzygy (or suture); for there must have been some amount of play between the successive joints, and a syzygy was described by Müller as an immovable sutural union of two joints.[2]

Next to *Hyocrinus*, the Pentacrinidæ have the most closely united stem-joints. In this family each internode of the stem contains five oval bands of elastic fibres (Pl. XXIV. figs. 1, 3–5, *ls*). They run through all the joints between the hypozygal of one syzygy and the epizygal of the next below it, which is the true nodal joint. Müller[3] and Wyville

[1] Notice of new living Crinoids belonging to the Apiocrinidæ, *Journ. Linn. Soc. Lond.* (Zool.), vol. xiii. p. 52, 1876.
[2] *Op. cit.*, p. 39.
[3] *Op. cit.*, p. 17.

Thomson[1] described them as extending from end to end of the stem; but this is not strictly true. At the top of the stem where the young nodal joints are very close together and of no great thickness (Pl. XIII. fig. 1; Pl. XV. fig. 1; Pl. XXXI. fig. 2; Pl. XXXVII. figs. 1, 2; Pl. XXXIX. fig. 1; Pl. XLIII. fig. 2; Pl XLIX. fig. 2), these bands of ligament are, no doubt, directly continuous from their attachment to the basals above, through more or fewer of the last-formed nodes and internodes. But this is certainly not the case in the lower parts of the stem. For after it has been decalcified the nodal and infra-nodal joints which form the syzygies are just as readily separable from one another as they are after the animal matter has been removed by the action of hot alkalies. This would obviously be impossible if the fibrous bands passed right through the joints "from one end of the stem to the other;" while, as a matter of fact, their terminations in the substance of the nodal or infra-nodal joints may be readily traced by microscopic examination. They correspond to the five radiating petaloid figures which are so well known on the surfaces of the stem-joints of the Pentacrinidæ (Pl. XV. fig. 5; Pl. XXVI. figs. 17, 18; Pl. XXX. figs. 28–30; Pl. XXXa. fig. 7; Pl. XXXIX. figs. 4–10; Pl. XLI. figs. 2, 3, 6, 7, 16, 17; Pl. XLVII. figs. 3–5, 7–9); and they are characterised by a somewhat looser calcareous reticulation than exists in the remaining portions of the joint (Pl. XXIII. fig. 3). The apposed faces are more or less cut up into ridges with intervening furrows; and the ridges on the lower face of the one joint correspond to the furrows on the upper face of that below it. (Pl. XV. figs. 1, 2; Pl. XIX. figs. 2–5; Pl. XXVII. fig. 1; Pl. XXXVI.; Pl. XLI. figs. 1, 5; Pl. XLVII. figs. 1, 2, 6; Pl. XLIX. fig. 3). Hence, while the composition of the stem out of a large number of discoidal joints gives it a certain amount of motion, that motion is very limited; and it is probably only of a passive character, due to currents in the water, &c., and independent of the will of the animal. In this respect it differs from the rays and their subdivisions, the joints of which are united by pairs of muscular bundles (Pl. Vc. fig. 2, *m.*; Pl. VIIb. figs. 1, 5; Pl. VIIIa. fig. 7, *rm.*; Pl. XXXIX. fig. 13; Pl. XLI. fig. 11); and the contractions of these bundles are governed by an influence proceeding outwards from the fibrillar envelope round the chambered organ in the calyx (Pl. VIIb. figs. 1, 2; Pl. XXIV. figs. 6–8; Pl. LVIII. figs. 1, 3—*ch*) along the axial cords of the rays and arms (Pl. Vc. fig. 2. Pl. VIIb. figs. 1, 5–8; Pl. VIIIa. figs. 5, 7, 8; Pl. XXIV. fig. 9—*A*. Pl. LXII.).

Although there are no true articular surfaces on the stem-joints of the Pentacrinidæ in the sense in which that term is employed in anatomy, yet this is by no means the case in the Bourgueticrinidæ. In all the members of this family there are true articulations between the successive stem-joints, of the same nature as those between the cirrus-joints of all Crinoids, and between the two outer radials of most Comatulæ and of some species of *Pentacrinus*. But they are effected only through the agency of

[1] Sea Lilies, p. 3.

ligamentous bundles, muscles being confined exclusively to the rays and their subdivisions.

This ligamentous articulation of the successive cirrus-joints and of the stem-joints of the Bourgueticrinidæ is of a very simple nature. There is an articular surface around the opening of the central canal with a more or less marked fossa on either side of it (Pl. VIIa. figs. 7–11). The fossæ lodge the elastic inter-articular ligaments, which are of precisely the same nature as the tendinous cords in the stem of *Pentacrinus*; but they differ from these cords in being confined to the intervals between the elongated joints without traversing their substance (Pl. VIIa. fig. 1, *ls*).

The two ligaments may be of unequal size, as in the middle and outer portions of the cirri, whereby the prehensile power of these organs is much increased; or they may be of equal bulk, as in the lower portions of the cirri and between the stem-joints generally. In the former, however, the long axes of the terminal faces of any joint lie in the same plane; but in the stem-joints of the Bourgueticrinidæ this is by no means the case, for the long axes of the terminal faces cross one another at various angles (Pl. VIIIa. figs. 2, 3; Pl. IX. fig. 3). The outline of the interarticular ligaments of the middle and lower parts of the stem, as seen in optical or in longitudinal section, has a diamond shape with somewhat extended lateral angles. This is, of course, due to the fact that the fibres are longest in the centre of the stem, immediately around the vascular axis, and shortest towards the periphery where the fossæ are shallowest (Pl. VII. figs. 12, 13; Pl. VIIa. figs. 7–11; Pl. X. figs. 11–14).

But there are no fibres at all in the middle half of each joint, which is composed of the usual limestone network. Towards the upper part, however, the fibres (Pl. VIIa. fig. 1) become relatively shorter in the centre but longer and longer towards the periphery, and their ends approach more and more nearly to the middle planes of the two joints which they unite. By the time the joints become cylindrical and then discoidal immediately below the cup, the fibres are continuous through their whole length (Pl. VIIb.), as is the case in the upper stem-joints of *Pentacrinus* (Pl. LVIII. fig. 3, *ls*).

The articular surface which surrounds the opening of the central canal varies considerably in its character. In many cirrus-joints it is merely an expansion of the thickened rim of the opening, but does not extend across the joint face. Quenstedt figures a stem-joint of this kind from the Mæstricht chalk.[1] It is nominally referred to *Bourgueticrinus ellipticus*, but I have seen no recent ones like it. In other cirrus-joints and in the stem-joints of the Bourgueticrinidæ the articular surface takes the form of a more or less well-marked ridge, which lies either across or in the direction of the long axis of the oval joint-face, and is pierced in the middle by the opening of the central

[1] Encriniden, Tab. 104, fig. 70.

canal; while the fossæ for the attachment of the ligaments are on either side of it (Pl. VIIa. figs. 7–11; Pl. X. figs. 11–14).

A similar mode of articulation occurs between the two outer radials of most Comatulæ and of a few species of *Pentacrinus* (Pl. XXX. figs. 11, 12; Pl. XXXII. figs. 16, 17; Pl. XXXIV. figs. 3, 6), as well as in the fossil *Extracrinus*, *Apiocrinus*, and *Millericrinus*. It is likewise very common between the first two joints after the radial and every other successive axillary, in those species which have branching arms; and also between some of the lowest pinnule joints. It has often been incorrectly described as a syzygy or a modified syzygy, though clearly distinguished therefrom by Müller[1] and by Dr. Carpenter.[2] Each of the two apposed faces is divided into two lateral halves by a vertical ridge pierced by the opening of the central canal, around which it is more prominent than at its ends. These fossæ lodge the strong interarticular ligaments, and no muscular bundles are interposed between the two joints. They are only capable of lateral movement upon one another, and cannot take part in any movements of flexion or extension, in which they act as a single segment only.

A peculiar modification of this bifascial articulation, as it may be called, occurs in *Bathycrinus*. It is naturally best seen between the two outer radials (Pl. VIIa. fig. 16) and the two lowest brachials, on account of their larger size; but it may be traced all through the arms (Pl. VIIa. figs. 20, 22). It was wrongly described as a syzygy by Sir Wyville Thomson in *Bathycrinus aldrichianus*,[3] and also by Danielssen and Koren in *Bathycrinus carpenteri*.[4] The vertical articular ridge is relatively large, and the two fossæ at its sides small in proportion (Pl. VIIa. figs. 16, 20, 22, *li'*). But at its lower end is a small though tolerably deep pit (*ld'*), which lodges a bundle of closely set ligament-fibres corresponding to those forming the dorsal ligament in an ordinary muscular joint (Pl. VIIb. fig. 5, *ld*). This bundle probably enables the two joints to take a larger share in the movements of flexion and extension than is possible in the bifascial articulations of the other Crinoids. The three ligaments, viz., the two lateral ones (*li*) and the median one on the dorsal side (*ld*) are all seen in section in Pl. VIIb. fig. 8.

A side view of a decalcified arm shows that there is a greater length of ligament between the two joints united in this way than there is between two joints which are united by syzygy in the much larger arm of a *Pentacrinus;* and though its length is but little greater than that of the fibres forming the syzygies in the arms of *Rhizocrinus rawsoni*, yet the latter are less numerous than in the trifascial articulation of *Bathycrinus*, especially on the upper (ventral) side of the central canal.

In all the four species of *Bathycrinus* which are considered in this Report, a trifascial articulation, like that between the two outer radials, occurs between the first and second,

[1] *Op. cit.*, pp. 26, 30. [2] *Op. cit.*, pp. 715, 716. [3] *Journ. Linn. Soc. Lond.* (Zool.), vol. xiii. p. 50, 1876.
[4] Ilycrinus carpenterii, *Nyt Magazin for Naturvidenskaberne*, Bd. xxiii. pp. 6–8 (of separate copy).

the fourth and fifth, and the seventh and eighth brachials (Pl. VII. fig. 2). The third brachial is articulated by muscles and ligaments to those before and behind it, as are also the sixth and ninth brachials. Beyond this point trifascial and muscular articulations alternate with one another throughout the arm. But those brachials which are united to their successors trifascially bear no pinnules as the remaining joints do; and in this respect they lose their morphological value as arm-joints, just as the hypozygal of a syzygium does. From this point of view, therefore, the description of the trifascial articulations as syzygia is perfectly correct. But they do not correspond to Müller's definition of a syzygy as an immovable sutural union of two joints. They occupy a curiously intermediate position between a bifascial articulation and a syzygy proper; for they resemble the former in the movement of the joints upon one another, and the latter in their occurring throughout the whole length of the arms, and in the absence of a pinnule on the lower joint of every pair so united. They correspond exactly in their distribution to the syzygies of *Rhizocrinus*, which come nearest to them in character, being perfectly plain and simple, and not marked with radiating ridges as in the Comatulæ and some Pentacrinidæ. But the trifascial articulation must not be confounded with the peg and socket form of syzygy which is met with in *Rhizocrinus* (Pl. X. figs. 1, 6, 8, 17, 18). In both cases there is a pit near the dorsal edge of one of the apposed faces; but in *Bathycrinus* this lodges a ligament (Pl. VIIb. fig. 8, *ld*) which is attached in a corresponding pit in the other face (Pl. VIIa. figs. 16, 22, *ld'*); while in *Rhizocrinus* this other face bears a peg-like process (Pl. X. fig. 17) which fits into the pit, and thus checks rather than facilitates motion.

It is noteworthy that there seems to have been a trifascial articulation between the two outer radials of the fossil *Apiocrinus insignis*, d'Orbigny, for the articular face of the second radial is described by de Loriol[1] as presenting "un bourrelet vertical large, épais et bifurqué près du bord externe." The fork of this ridge at its dorsal end gives the joint-face an altogether different appearance from the corresponding part in *Apiocrinus parkinsoni*, and it is difficult to see what can have been lodged in the fossa between the two limbs of the fork, except a third ligamentous bundle such as occurs in *Bathycrinus*.

In all the Neocrinoidea muscular articulations occur between the first and second radials, between every axillary and the two joints which it bears, and between most of the following arm-joints (Pl. III.; Pl. VIIa. figs. 15, 17, 18, 19, 21, 23; Pl. X. figs. 1–4; Pl. XII. figs. 3–6, 8, 9, 12, 19, 20, 23; Pl. XXI. figs. 1*a*, 1*b*, 2*a*, 2*b*, 3*b*, 4*b*, 4*c*, 5*c*, 6*d*, &c.). When the arms divide and the axillaries are simple, they may be united by muscles to the preceding joints in *Pentacrinus* and *Metacrinus* (Pl. XII. fig. 3); though this is never the case in the Comatulæ. But if the axillaries are syzygial joints, there is always a muscular articulation below the hypozygal. No

[1] Paléontologie Française. Terrain Jurassique, t. xi. Crinoides, p. 309, pl. lvi. fig. 2c.

muscles are ever found between the second and axillary radials of any Neocrinoid except *Eudesicrinus* (p. 215), nor (except in *Metacrinus*) between the first and second brachials, unless the latter be a syzygial joint. In the aberrant *Metacrinus*, however, the second radial is a syzygial joint (Pl. XII. figs. 7–10) and the axillary is usually either the fourth or the sixth radial (Pl. XII. figs. 3, 4; Pl. XXXIX. fig. 1; Pls. XLII., XLIII., XLV., XLVI., XLVIII.–LI.); and there is usually a syzygy in the third joint after each successive axillary, just as in the free arms of most Comatulæ. But the first two joints are united by muscles instead of by ligaments, as in the Comatulæ; and I have not met with any instances of bifascial articulation in the arms of this genus, which have nothing but syzygies and muscular unions like the arms of *Actinometra solaris* or *Actinometra typica*.

Each pinnule has a muscular attachment to the arm-joint which bears it (Pl. Vc. fig. 2, *m*; Pl. VIIa. fig. 21; Pl. XVII. fig. 1; Pl. XXXa. figs. 10*a*, 12*a*; Pl. XLI. fig. 11; Pl. XLVII. figs. 11, 12); while in *Metacrinus* and some tropical Comatulæ the lower joints of the pinnules are united by muscles instead of by ligaments or suture only (Pl. XIII. fig. 12).

The articular face of a joint which is connected with its successor by muscular bundles presents a variety of fossæ separated by intervening ridges, that are frequently somewhat ill defined (Pl. VIIa. figs. 15, 17, 18, 19, 21, 23; Pl. X. figs. 1–4; Pl. XII. figs. 3–6, 8, 9, 12, 15, 19, 20, 23; Pl. XXI. figs. 1*a*. 1*b*, 2*a*, 2*b*, 3*b*, 4*b*, 5*c*, 6*d*, &c.). Beneath its upper and lateral edges lie the two fossæ in which the muscular bundles are attached (Pl. VIIa. fig. 15, *rm'*). They are sometimes separated by a vertical ridge as on the first radials of *Antedon phalangium*, *Antedon eschrichti*, and of most species of *Antedon* and *Promachocrinus*; and sometimes by a groove which may extend downwards to the articular rim around the opening of the central canal, as in the first radials of *Antedon rosacea* and most species of *Actinometra* and *Pentacrinus* (Pl. XXI. fig. 6*d*). In these last types the fossæ are comparatively small; but in *Promachocrinus* and in most species of *Antedon* they occupy nearly or quite half of the articular face, as in *Bathycrinus aldrichianus* (Pl. VIIa. fig. 15, *rm'*; Pl. VIIb. fig. 5, *rm*). Below the muscular fossæ, and separated from them by more or less distinct ridges, are those lodging the interarticular ligaments (Pl. VIIa. fig. 15, *li'*; Pl. VIIb. fig. 5, and Pl. VIIIa. fig. 7, *li*). They are bounded below by the transverse articular ridge, which is pierced by the opening of the central canal. This is usually surrounded by a more or less prominent rim, from which the ridges start that separate the muscular fossæ from the ligamentous ones and from one another. All these characters are much less distinct in the Pentacrinidæ than in the Comatulæ.

Beneath the transverse ridge, and bounded below by the curved edge of the articular face is a large fossa extending right across the face and lodging the dorsal elastic ligament (Pl. VIIa. fig. 15, *ld'*; Pl. VIIb. fig. 5, and Pl. VIIIa. fig. 7, *ld*). As a general rule this ligament is chiefly concentrated in a small, more or less oval pit situated

immediately beneath the articular ridge (Pl. X. figs. 1–4; Pl. XX. fig. 7; Pl. XXXa. fig. 11*a*; Pl. XXXII. figs. 6, 8–11, 15), and corresponding to the single pit which lodges the third ligamentous bundle in the trifascial articulations of *Bathycrinus* (Pl. VIIa. figs. 16, 20, 22, *ld'*). In *Millericrinus*, and more especially in *Apiocrinus*, the portion of the dorsal fossa outside this central pit is enormously expanded; and the true articular surface becomes relatively insignificant.

The pairs of fossæ are symmetrical on the two sides of each articular face in the first and second radials (Pl. VIIa. fig. 15; Pl. XII. figs. 20, 23; Pl. XXI. figs. 5*e*, 6*d*); but in the ordinary arm-joints, which have more or less oblique terminal faces and bear pinnules at their sides (Pl. VIIa. fig. 21; Pl. XXI. figs. 4*b*, 4*c*), there is a disturbance of the symmetrical arrangement of ridges and fossæ which is so very evident in the calyx of all Neocrinoids (Pl. VIIb. fig. 5; Pl. VIIIa. fig. 7; Pl. X. figs. 1, 4; Pl. XII. fig. 15; Pl. XVIII. fig. 4; Pl. XXX. fig. 3; Pl. XXXIV. fig. 7), with the exception of *Holopus* and its allies (Pl. III. figs. 1, 2; Pl. V. fig. 1).

II.—THE STEM AND ITS APPENDAGES.

We have already seen that three types of stem occur in the recent Crinoids, which are characteristic respectively of the families Pentacrinidæ, Bourgueticrinidæ, and Hyocrinidæ. Broadly speaking, it may be said that these embrace all the varieties of stem which are met with in the Neocrinoidea. For the mode of union of the joints in *Apiocrinus*, *Millericrinus*, and *Eugeniacrinus* must have been very much what it is in *Hyocrinus*; though the "root" of the first-named genus is somewhat peculiar in its nature.

A. Pentacrinidæ.

In all the genera of this family the stem consists of discoidal joints which are never (in the adult) higher than wide, and have the characteristic petaloid markings on their terminal faces (Pls. XI., XIV.; Pls. XV. figs. 4, 5; Pls. XIX., XXII; Pl. XXVI. figs. 12–18; Pls. XXVIII., XXIX; Pl. XXX. figs. 25–30; Pl. XXXa. figs. 1–7; Pl. XXXVII. figs. 10–22; Pl. XXXIX. figs. 3–11; Pl. XLI. figs. 1–5, 6–8, 15–17; Pl. XLVII. figs. 1–9). Certain of these joints, separated from each other by intervals of variable length, bear whorls of cirri, and they have consequently received from Sir Wyville Thomson[1] the very appropriate name of "nodal joints." There are usually five cirri at each node, situated in the direction of the rays (Pls. XI., XVIII., XIX., XXXIV.–XXXVI., XL., XLII.–XLVI., XLVIII.–LII.). Sometimes, however, one cirrus is deficient, as shown in the left hand figure on Pl. XXXVI.; while in *Pentacrinus alternicirrus* there are only three cirri at one node, and two at each of those above and below it, the positions of these two corresponding to the two gaps at the node of three cirri (Pl. XXV.; Pl. XXVI. figs. 13, 14; Pl XXVII. figs. 1–3). The cirri of two successive nodes therefore alternate in position as the leaves do in the stem of a Labiate plant, the two faces of the stem which bear no cirri at one node being the only ones which have cirri at the nodes above and below it.

The function of the cirri, which vary considerably both in length and in stoutness, is described by A. Agassiz[2] as follows:—"These they move more rapidly than the arms, and use them as hooks to catch hold of neighbouring objects, and on account of their sharp

[1] Sea Lilies, p. 7.

[2] Letter No. 3, on the dredging operations of the U. S. Coast Survey, Sr. "Blake," from December 1878 to March 10, 1879, *Bull. Mus. Comp. Zoöl.* vol. v. No. 14, p. 296.

extremities they are well adapted to retain their hold. The stem itself passes slowly from a rigid vertical attitude to a curved or even drooping position."

The shape of the nodal joints is markedly different from that of the internodal joints which separate them. They are not only somewhat higher (Pl. XIX. figs. 3, 4; Pl. XXVI. fig. 12; Pl. XXVII. fig. 1; Pls. XXXV., XXXVI.; Pl. XXXIX. fig. 3; Pl. XLI. figs. 1, 5, 15; Pl. XLII.; Pl. XLV. fig. 6; Pl. XLVII. figs. 1, 2), but the outline of the upper non-syzygial face is different from that of an internodal joint. (Compare Pl. XXXIX. figs. 4, 8; Pl. XLI. figs. 2, 3, 6, 7, 16, 17; Pl. XLV. figs. 2, 4; Pl. XLVII. figs. 4, 5, 8, 9; Pl. LI. figs. 9, 10; Pl. LIII. figs. 3, 4.) In the recent *Pentacrinus* and *Metacrinus* every nodal joint is united by syzygy to the top joint of the next internode below. I propose to give the name "infra-nodal" to this joint, which is really the hypozygal of the syzygial pair (Pl. XXII. figs. 19–22; Pl. XXVI. figs. 12–16; Pl. XXX. figs. 26–29; Pl. XXXVII. figs. 5–8, 19–22; Pl. XXXIX. figs. 3–7; Pl. XLV. figs. 3–5; Pl. XLVII. figs. 3, 7; Pl. L. figs. 19–22; Pl. LIII. figs. 3, 5). The apposed faces of these two joints are much more distinctly stellate than are those of the remaining stem-joints, the re-entering angles of the star being the points of attachment of the cirri, and the syzygial surfaces of the mature joints are almost smooth and devoid of any markings whatever.

The syzygial union of two stem-joints is effected, just as it is in the rays and arms, by short fibrils of connective tissue, very numerous and closely set. They form a kind of "cement substance," as it was formerly called, which is connected at its ends with the organic basis interpenetrating the calcareous network of the stem-joints, just as the "cement-substance" of the arm-syzygies is connected with the organic basis of the brachials. But these fibrils are absolutely distinct from those of the five long ligamentous bundles which occupy the internodes. The latter are often spoken of as tendons, and have been wrongly described as extending throughout the whole length of the stem. Were this really the case, it is difficult to see how the stem could break across at the syzygies so easily as it does; for there would be no reason why the five tendons should be weaker at these points than at anywhere else in the internodes, while the loose ends of the tendons should appear at the surfaces of fracture, just as they do where an internode is forcibly broken across. But this is not the case; when the stem is decalcified the joints separate very readily along the lines of syzygy, and it is then apparent that the five tendons run from the lower portion of each infra-nodal joint down into the upper portion of the next nodal joint below it. They end within these two joints, just as do the ligaments which connect two brachials, terminating either in looped extremities or else passing into the connective tissue plexus which forms the substance of all the joints whether of arm or stem.

The various internodal joints are, as it were, strung upon these tendons, which are thus not continuous, but divided up into lengths, each corresponding to an internode;

and there is no more direct communication between the fibres forming one of the tendons that ends in a nodal joint and the fibres of the syzygy between that joint and the infra-nodal, than there is between the ligaments uniting the second radials of *Pentacrinus wyville-thomsoni* to the first (Pl. XXIV. figs. 8, 9, *ld*), and the fibrils of the syzygy between the second and third radials. In both cases the two sets of fibres are separated by the organic basis of a joint of the skeleton; in the one of the ray, and in the other of the stem.

The amount of increase in the size of the nodal joint varies considerably in the different species. They are not specially prominent in *Pentacrinus asteria* (Pl. XIII. figs. 4, 8), *Pentacrinus mülleri* (Pl. XV. fig. 4), *Pentacrinus blakei* (Pl. XXXI. fig. 3), or in *Pentacrinus naresianus* (Pl. XXVIII. fig. 2; Pl. XXXa. fig. 6). In *Pentacrinus decorus*, on the other hand (Pl. XXXVI.), the joint expands considerably from its upper edge down to the top of each cirrus-socket, and then narrows again; while in *Pentacrinus wyville-thomsoni* (Pl. XIX. figs. 3, 4) the sockets are very prominent, and the joint is widest near its lower edge. In the genus *Metacrinus*, however, the cirrus-sockets are by no means specially prominent (Pl. XXXIX. fig. 3; Pl. XLI. figs. 1, 5, 15; Pl. XLVII. figs. 1, 2; Pl. XLIX. fig. 3; Pl. LI. figs. 6–8; Pl. LII. fig. 2; Pl. LIII. fig. 6).

In *Pentacrinus asteria* (Pl. XIII. figs. 4, 8) and *Pentacrinus mülleri* (Pl. XV. fig. 4), the sockets are usually more or less transversely oval in shape and well defined below, so as to be almost or entirely limited to the nodal joint. In *Pentacrinus decorus*, however, the articular surface occupies the broad end of a pear-shaped depression, which is continued down on to the infra-nodal joint (Pl. XXXVI.), and thus gives it a distinctly stellate outline even when seen from beneath (Pl. XXXVII. figs. 10, 20); while the ordinary internodal joint has a rounded or pentagonal outline. The lowest internodal or "supra-nodal" joint of this species is in no way different from the other internodal joints above it; while the infra-nodal is hollowed laterally by the downward extensions of the cirrus-sockets (Pl. XXXVI.; Pl. XXXVII. figs. 8, 19). In *Pentacrinus wyville-thomsoni*, however, the lower edge of the socket projects outwards beyond the level of the infra-nodal (Pl, XIX. figs. 3, 4). This joint is but little different from those below it, except just at its upper edge where it meets the enlarged surface of the nodal joint that rests on it (Pl. XXII. figs. 21, 22). The supra-nodal joint, on the other hand (Pl. XXII. fig. 17), is not so round as the remaining stem-joints (fig. 23); for it is slightly hollowed by the upper portions of the cirrus-sockets, and thus more nearly approaches the shape of the upper face of the nodal joint on which it rests (fig. 18).

This condition becomes still more marked in *Metacrinus*, which has relatively low nodal joints with wide and comparatively inconspicuous sockets (Pl. XXXIX. fig. 3; Pl. XLI. figs. 1, 5, 15; Pl. XLVII. figs. 1, 2; Pl. LI. figs. 6–8; Pl. LII. fig. 2; Pl. LIII. fig. 6), just as in *Pentacrinus asteria* and *Pentacrinus mülleri* (Pl. XIII. figs. 4, 8; Pl. XV. fig. 4); but both supra- and infra-nodal joints share in the formation of the cirrus-socket,

the re-entering angles of the former being deeper than those of an ordinary internodal joint. (Compare Pl. XXXIX. figs. 8, 9; Pl. LIII. figs, 2, 4).

The occurrence of syzygies in the stem of the Pentacrinidæ has long been familiar to palæontologists. This is due to the fact that the stem breaks most easily at these points, so that stem fragments are not uncommon in the fossil state with syzygial faces at one or both ends. This has been noticed both by Quenstedt[1] and by de Loriol[2]; but these fragments have sometimes been figured in an inverted position, the syzygy being represented as at the upper surface of the nodal joint, whereas it is naturally at the under surface.

Within each nodal joint the vascular axis of the stem expands into a miniature edition of the chambered organ in the calyx (Pl. XXIV. figs. 3, 4, *ch.n.*); and from each chamber is given off one cirrus-vessel (fig. 4, *cv*). This is sheathed in a very delicate extension of the fibrillar envelope of the vascular axis (*ca*), and passes outwards into the central canal of the cirrus.

The number of internodal joints varies very considerably in the different species of Pentacrinidæ. There may be only one or two as in *Pentacrinus maclearanus* (Pl. XVI.); or the number may reach forty-five, as in the lowest parts of the stem of *Pentacrinus wyville-thomsoni* (Pl. XIX. fig. 1), or any lesser figure (Pls. XI., XIV., XXVIII., XXXIV.–XXXVI., XXXVIII., XL., XLII., XLIV., XLV., XLVIII.–LIII.) These internodal joints are sometimes smooth externally (Pl. XI.; Pl. XIII. fig. 8; Pl. XIX. figs. 1–5; Pl. XXVII. fig. 1; Pl. XXVIII. fig. 2; Pl. XXXa. fig. 6; Pl. XXXI. fig. 3; Pl. XXXV. fig. 2; Pl. XLI. figs. 5, 15; Pl. XLII.–XLIV.; Pl. XLVII. fig. 6); or they may be more or less ornamented with ridges and tubercles (Pl. XIII. fig. 7; Pl. XXXV. fig. 1; Pl. XXXVI.; Pl. XXXVIII.; Pl. XXXIX. figs. 3, 8–11; Pl. XL.; Pl. XLI. fig. 1; Pl. XLV. figs. 1, 6; Pl. XLVII. figs. 1, 2; Pl. LI. fig. 8; Pl. LII. fig. 2; Pl. LIII. figs. 2, 4–6). The young joints formed at the top of the stem are stellate or nearly pentagonal (Pl. XIII. fig. 9; Pl. XXII. figs. 1–12; Pl. XXIII; Pl. XXVI. fig. 18; Pl. XXXIV. fig. 9; Pl. XXXVII. figs. 13–16), so that the upper part of the stem is marked by five more or less prominent interradial ridges (Pl. XI.; Pl. XIII. fig. 1; Pl. XV. figs. 1, 2; Pl. XVIII. figs. 1, 2; Pl. XIX. figs. 1, 6, 7; Pl. XXXI.; Pls. XXXV.–XXXVII.; Pl. XXXIX. fig. 1; Pl. XLIII.). In some species (of *Metacrinus* especially) this condition is retained throughout the whole length of the stem (Pl. XXXVIII.; Pl. XXXIX. figs. 3–11; Pl. XL.; Pl. XLIX. figs. 1–3); but in others the joints gradually become more rounded, or at any rate pentagonal, as new ones are formed successively above them (Pl. XI.; Pl XIII. fig. 11; Pl. XIX. figs. 1, 4, 5; Pl. XXII. figs. 13, 14, 23–26; Pl. XXVIII. fig. 2; Pl. XXX. figs. 25–30; Pl. XXXVI.; Pl. XLI. figs. 3, 7; Pl. XLVII. figs. 4, 8). A continual production of new joints goes on at the top of

[1] Encriniden, pp. 196, 230, Tab. 98, figs. 2, 3, 107.

[2] Monographie des Crinoïdes fossiles de la Suisse, *Mém. Soc. Pal. Suisse*, 1877–79, pp. 122, 144.

the stem immediately beneath the calyx, what appears to be the top stem-joint in a side view having one or two more smaller joints resting in its upper surface but not reaching the exterior as shown in Pl. XXXIV. fig. 9.

The top stem-joint—for the time being—of a specimen of *Pentacrinus wyville-thomsoni* is shown in Pl. XXII. fig. 2. Resting on its upper surface is a smaller stellate plate without any markings whatever, which in its turn would appear as the top stem-joint until it was replaced by the development of another above it. As these joints are relatively carried downwards from the calyx in succession by the appearance of younger ones above them, they also become separated from one another by the intercalation of new joints between them. Various stages of this process are shown in Pl. XXII. figs. 9–12, while fig. 4 shows an isolated young joint, and fig. 5 the depression in the next joint, which lodged it. Similar intercalated joints are shown in Pls. XXII. fig. 3, and Pl. XXIII. figs. 1, 2. The result of this process is that the growing part of the stem appears to consist of thick and thin joints alternating with one another (Pl. XIII. fig. 1; Pl. XIV.; Pl. XV. figs. 1, 2; Pl. XVIII. fig. 1, 2; Pl. XIX. fig. 2, 6, 7; Pls. XXV., XXVIII.–XXX.; XXXIV.–XXXVII.; Pl. XXXIX. fig. 1; Pl. XLIII. fig. 2; Pl. XLVIII. fig. 2). The former are the older, the latter being subsequent additions. These intercalated joints are always internodal, and the process goes on until the number of joints between any two nodes reaches a certain average, which is constant for each individual species.

There are many indications that the increase in length of the stem of the fossil Pentacrinidæ was due to the same process. Quenstedt[1] gives an excellent figure of a young concealed joint superposed upon an older and larger one, very much as shown in Pl. XXII. figs. 9–12; and others of his figures upon the same plate illustrate the different stages of growth on the stem of *Extracrinus subangularis*, as many as three or four concealed joints being sometimes found intercalated between two of the larger ones. In this species, too, with a stem which may reach 50 or 70 feet in length, the production of nodal joints at the top of the stem must have been very rapid. According to Quenstedt[2] forty or more succeed one another without any internodal joints being visible externally, though the presence of concealed intercalated joints is revealed by the examination of longitudinal sections of the stem. The final result of their growth was to enormously increase the total number of internodal joints.

Stem-fragments have been found by Quenstedt consisting of as many as eighty joints, all internodal, and it is impossible to say how many more there may have been; while he states that he finds traces of small intercalated joints in almost every part of the stem.

In most cases the new joints which have been intercalated between two older ones eventually reach the same size as their predecessors, so that it is difficult to tell the older from the younger joints in any mature stem. But in some species there appears to

[1] Encriniden, p. 298, Tab. 101, figs. 24*a*, 24*b*.

[2] *Ibid.*, p. 297, Tab. 101, figs. 16–19.

be a permanent inequality, large and small joints alternating all down the stem. This is the case, for example, in the fossil *Pentacrinus jaccardi* and *Pentacrinus nicoleti* figured by de Loriol,[1] and also to some extent in the recent *Metacrinus moseleyi* (Pls. XLV., XLVI.).

There is very little difference between the upper and the under faces of the young nodal joints, or between either of them and the ordinary internodal joint (Pl. XXII. figs. 1, 6–8, 15; Pl. XXXa. figs. 2, 3; Pl. XXXVII. figs. 14–16; Pl. LI. figs. 2–5). But as the joints become older and more pentagonal their differences are more apparent (Pl. XIII. figs. 2, 3, 5, 6, 10; Pl. XXII. figs. 16–18; Pl. XXXVII. figs. 11–13, 17, 18); while in the lower part of the stem the simple syzygial nature of the under face of the nodal joint and its loss of the denticulate petaloid markings become very distinct (Pl. XV. fig. 6; Pl. XXII. figs. 19, 20; Pl. XXVI. figs. 13, 14; Pl. XXVII. figs. 2, 3; Pl. XXX. figs. 26, 27; Pl. XXXVII. figs. 21, 22; Pl. XXXIX. figs. 4, 5; Pl. XLV. figs. 4, 5; Pl. L. figs. 21, 22).

In some species of *Pentacrinus, e.g., Pentacrinus wyville-thomsoni*, the lowest and therefore the oldest stem-joints gradually lose the more or less prominent ridges which appear on the faces of those higher up the stem, and become much more smooth and simple in their character (Pl. XXII. figs. 23–26).

A similar change seems to take place in *Pentacrinus asteria* (Pl. XIII. figs. 10, 11), and also in other species, though I have not been able to trace it so distinctly as in *Pentacrinus wyville-thomsoni*. It is manifested externally by the gradual disappearance of the crenulation of the interarticular lines, which is so very prominent in the upper and middle parts of the stem (Pl. XIII. figs. 7, 8; Pl. XV. figs. 1, 2, 4; Pl. XIX. figs. 2–5; Pl. XXV.; Pl. XXVII. fig. 1; Pl. XXXI. fig. 3; Pls. XXXV.–XXXVII.; Pl. XLI. figs. 1, 5, 15; Pl. XLIII. fig. 1).

The amount of crenulation varies considerably in different species, according to the position of the large teeth bordering the outer ends of the petaloid spaces. When these start from near the edge of the joint, as in *Metacrinus cingulatus, Metacrinus nobilis*, or *Metacrinus costatus* (Pl. XLI. figs. 1–3, 5–7; Pl. XLIX. figs. 3–5), the interarticular line is well crenulated. But there is sometimes a sort of rim outside the ends of the teeth, as in *Metacrinus murrayi* and *Metacrinus varians* (Pl. XLI. figs. 15, 17; Pl. XLVII. figs. 6–9), and the external crenulation is then less marked. This outer rim is only formed comparatively late, the teeth of a young joint starting directly from its edge, as is well shown in Pls. XXII., XXIII., and XXXVII.

The increase in the length of the internodes only takes place gradually, and *pari passu* with the continual formation of new joints just below the calyx. Hence, in the upper part of the stem, there is a variable number of premature internodes, those nearest the summit being the shortest, and consisting of the smallest number of joints. The

[1] Swiss Crinoids, pp. 130, 140, pl. xv. figs. 13, 36.

upper part of the stem is also distinguished from the more fully grown portion below it by the presence of the "interarticular pores." These are small pore-like openings between the successive joints which are situated in the re-entering angles between the interradial ridges, and are therefore radial in position (Pl. XI.; Pl. XIII. fig. 7; Pl. XV. figs. 1, 2; Pl. XIX. figs. 2, 3; Pl. XXV.; Pls. XXVIII., XXIX., XXXIV.–XXXVIII., XLIV., XLVIII.; Pl. XLIX. fig. 2; Pl. L. figs. 1, 3). They are produced by the apposition of two faint grooves radiating outwards from the centres of the contiguous joints, which are largest at their central ends and shallowest towards the periphery (Pl. XIII. fig. 9; Pl. XXII. figs. 8, 10, 12; Pl. XXXVII. figs. 10–18, 20, 22). They do not reach the central canal of the stem; and so there is no communication effected by the agency of these pores between the internal vascular axis and the exterior. Similar openings occur in many Comatulæ, leading into spaces between the upper surface of the centro-dorsal and the under surfaces of the radials which rest upon it;[1] but they effect no communication between the body-cavity and the external medium.

Until comparatively lately but little has been known respecting the termination of the lower part of the *Pentacrinus* stem. Nearly all the specimens obtained had a fractured stem, from which no conclusions could be drawn. From what we know of the development of the Comatulæ we may fairly assume that the young *Pentacrinus* commences life attached to some foreign body by means of a terminal plate (the dorso-central) at the base of its stem, and a calcareous expansion subsequently developed around it. Mature individuals have been found attached in this way to telegraph cables. Capt. E. Cole of the telegraph steamer "Investigator" has reported to Prof. Agassiz "that he has frequently brought up the West India telegraph cable on which *Pentacrini* were attached, and that they are fixed, the basal extremity of the stem spreading slightly, somewhat after the manner of *Holopus*, so that it requires considerable strength to detach them."[2] The condition of the lower part of the stem fragment of *Pentacrinus naresianus*, represented in Pl. XXXa. fig. 4, is perhaps due to this mode of attachment.

At the same time there appears to be ample evidence that a Pentacrinite may lead the same sort of free life that a *Comatula* does, attaching itself temporarily by its cirri. Sir Wyville Thomson long ago pointed out, in the case of *Pentacrinus decorus*,[3] "that the animal seems to have had the power of detaching itself" at any of the syzygies of the stem in the same sort of way as the arms are thrown off during life, or break up after death. He described an individual in which the stem terminated below in a worn and rounded nodal joint, and he supposed it "to have finally parted from its attachment and to have led a free life." He stated some years afterwards that this was the case in all the complete specimens which he had seen, "showing that the animal must have been for long free from any attachment to the ground."[4] He then went on to describe the same

[1] The Genus Actinometra, *loc. cit.*, pp. 88–90, pl. viii. figs. 5, 7.

[2] *Bull. Mus. Comp. Zoöl.*, vol. v. No. 14, p. 296.

[3] Sea Lilies, p. 7.

[4] The Depths of the Sea, pp. 442–444.

condition as it occurs in *Pentacrinus wyville-thomsoni*. "All the stems of mature examples of this species end inferiorly in a nodal joint surrounded by its whorl of cirri, which curve downwards into a kind of grappling root. The lower surface of the terminal joint is in all smoothed and rounded, evidently by absorption, showing that the animal had for long been free. I have no doubt whatever that this character is constant in the present species, and that the animal lives loosely rooted in the soft mud, and can change its place at pleasure by swimming with its pinnated arms; that it is, in fact, intermediate in this respect between the free genus *Antedon* and the permanently fixed Crinoids."

Many other species of *Pentacrinus* and some of *Metacrinus* exhibit the same condition. It is best seen in *Pentacrinus wyville-thomsoni*, in which the nodal joint sometimes loses its ordinary characters altogether, becoming much enlarged and rounded below so as to be almost hemispherical in appearance (Pl. XXII. fig. 27).[1] In other cases, however, it retains its petaloid form and more or less of the small amount of sculpture which is usually found upon its lower face; and a small rounded tubercle appears in the centre of the latter closing up the opening of its central canal. This is the usual condition of other species of *Pentacrinus* (*e.g.*, *Pentacrinus asteria*, Pl. XI.) and of *Metacrinus;* and the analogy between it and the condition of a young *Comatula* just detached from its stem is very striking, as was pointed out by Sir Wyville Thomson.[2] In both cases the severance takes place between a nodal joint and the top joint of the internode below it.

The relations of the two longest stems that I have met with in this condition are shown as follows:—

Pentacrinus decorus, stem 48 cm. long, rounded off at the thirtieth node.

Metacrinus angulatus, stem 38·5 cm. long, rounded off at the thirty-fifth node.

With one exception (*Pentacrinus maclearanus*, Pl. XVI.) the three shortest of these semi-free stems that I have examined all belong to *Pentacrinus alternicirrus*. A, 47 mm. long, ends at the eleventh node; B, 49 mm., ends at the eleventh node; and C, 55 mm., ends at the twelfth node. On the other hand, the smallest number of nodes in a semi-free stem occurs in *Pentacrinus wyville-thomsoni;* one individual having a stem 90 mm. long, which

[1] The unusual enlargement of the lowest nodal joint in this individual suggests the idea that the structures which have been described by Hall under the name of *Ancyrocrinus* (Fifteenth Annual Report, New York State Cabinet of Natural History, 1862, pp. 89, 90) may be the detached stems of a Palæocrinoid in the semi-free condition. According to Hall they "have the form of a bulb or thickened column, with lateral ascending processes and a central ascending column of greater or less length;" and he suggests that they "indicate the existence of a free floating Crinoid with the thickened bulb below serving as a balance for the column and body above. The articulating scar on the lower extremity of the smaller ones indicates that the animal was fixed in its young state." The four lateral spine-like processes may very well have been cirri, the jointed structure of which has become obliterated by a calcareous overgrowth, just as in the lower part of the tetramerous stem.

[2] Sea Lilies, p 10.

ends at the sixth node. This is due to the great length of the internodes in this species (Pl. XVIII. fig. 3; Pl. XIX. fig. 1).

Pentacrinus maclearanus presents exactly the opposite type of structure. There are only twelve nodes in the stem of the solitary individual obtained (Pl. XVI.). But these all occur in a stem barely 40 mm. long, as there are never more than two, and generally only one internodal joint; while the cirri cluster thickly round the stem, so that it has an appearance more like that of *Extracrinus briareus* than is commonly met with in the Pentacrinidæ. It is noteworthy that in the last-named species the stem does not seem to have reached any great length, and that it sometimes tapered downwards.[1]

This peculiarity was also noticed by MM. Eudes-Deslongchamps in some stems belonging to a large colony of Pentacrinites which they discovered in the Great Oolite of Soliers, near Caen;[2] while it is very characteristic of *Millericrinus pratti* from the same horizon in Gloucestershire;[3] and also of the Carboniferous *Woodocrinus*, certain Blastoids, and of the Silurian *Glyptocystites*, *Pleurocystites*, and other forms. The most remarkable instance of this in a fossil Crinoid, however, is that of the Lower Silurian *Glyptocrinus schafferi* of S. A. Miller,[4] for which he has recently established the new genus *Pycnocrinus*. In one specimen found by Miller the lower part of the stem was "wound around a Crinoid column of a distinct species, almost as neat as a thread can be wound upon a spool. The column gradually tapers as it coils, until it becomes so small as to be scarcely visible to the naked eye, the larger plates of the column which give it that banded appearance, or make it resemble a string of small spools, gradually diminish, and before the column terminates it becomes as smooth as a silken thread."

Two other species from the same locality at Cincinnati, *Lichenocrinus dubius* and *Dendrocrinus navigiolum*, were also found by Miller to have tapering stems. In the case of the former he infers that "the column was free and used to direct and guide the course of the animal through the water, and perform such other functions as were performed by the columns of other floating Crinoids, except that it was never used for purposes of attachment." One must not, however, conclude at once, from the tapering condition of the stem in a fossil Crinoid, that the animal was free in its habits. In a young *Eucalyptocrinus crassus*, for example, which is figured by Hall,[5] the stem tapers downwards very considerably, but is attached below by a spreading root.

I have found a tapering stem in certain individuals belonging to six species of recent Pentacrinidæ, but it appears to be the exception rather than the rule, and is therefore entirely devoid of any systematic value.

[1] Encriniden, p. 271.

[2] Études sur les étages Jurassiques inférieurs de la Normandie, Paris, 1864, p. 232.

[3] On some new or little known Jurassic Crinoids, *Quart. Journ. Geol. Soc.*, vol. xxxviii. pp. 31–33, pl. i. figs. 6–8, 10–14.

[4] Description of four new Species and a new variety of Silurian Fossils, and remarks upon others, *Journ. Cincinn. Soc. Nat. Hist.*, vol. iii., 1880, pl. vii. fig. 3, p. 2 (of separate copy).

[5] Twenty-eighth Annual Report of the New York State Museum of Natural History, Albany, 1879, pl. xvii. fig. 5.

In one example of *Pentacrinus alternicirrus*, which has a stem only 55 mm. in length, and rounded off at the twelfth node, the width diminishes gradually from above downwards, though not to any very great extent. The same is the case in another specimen with a stem 47 mm. long and rounded off at the eleventh node. In other examples of the same type, however, the width of the stem remains uniform or even increases slightly from above downwards. In a large specimen of *Pentacrinus naresianus* the width of the stem, which is 5 mm. at the eighth node, is reduced to 3·5 mm. by the thirtieth node, which is rounded off below.

In the young *Pentacrinus wyville-thomsoni* represented in Pl. XVIII. fig. 3, the stem is 65 mm. long; but it is not half as wide at the lowest (sixth) node as it is beneath the calyx. It was described by Sir Wyville Thomson[1] as follows:—"The stem is broken off in the middle of the eighth internode from the head. The lowest complete internode consists of fourteen joints, the next of eighteen, the next of twenty, and the next of twenty-six joints. There are eight joints in the cirri of the lowest whorl, ten in those of the second, twelve in those of the third, and fourteen in those of the fourth. This is the reverse of the condition in adult specimens, in all of which the numbers of joints in the internodes, and of joints in the cirri, decrease regularly from below upwards. The broken internode in the young example and the three internodes above it are all atrophied and undeveloped; and suddenly at the third node from the head the stem increases in thickness and looks as if it were fully nourished. There can be no doubt that in early life the Crinoid is attached, and that it becomes disengaged by the withering of the lower part of the stem."[2]

The diminution in the size of the stem is rather more gradual than is implied in the above description, for it commences at the head and extends regularly down to the third node, where there is a more sudden change, as there is again at the fourth, below which the diameter decreases but slowly.

But it is in a very young individual of *Pentacrinus decorus* (Pl. XXXV.), in fact the youngest Pentacrinite that I have seen, that this downward tapering of the stem and gradual diminution in the size of the cirri are most marked. The stem is a trifle over 60 mm. in length, and has ten distinct cirrus-whorls apart from the very small

[1] On the Crinoids of the "Porcupine" Deep-Sea Dredging Expedition, *Proc. Roy. Soc. Edin.*, vol. vii. p. 768. Also in the Depths of the Sea, p. 445.

[2] The above description requires a little correction. The stem in its present condition, as represented in Pl. XVIII. fig. 3, is broken at the top of the seventh internode, which is certainly the one referred to by Sir Wyville as the eighth. But its length is at least 5 mm. greater than as stated by him; and the number of joints in the two lowest internodes should be given as fifteen and seventeen, not fourteen and eighteen. They are drawn correctly in the figure, but the joints at the top of the third internode are not properly represented, as is also the case with some of the cirri. The figures of this and of the other plates drawn for Sir Wyville Thomson had been on stone for so long when the stalked Crinoids came into my hands after his death, that I thought it better to let any errors remain unaltered rather than to risk spoiling the plate by correcting them. The description given of the cirri is also only roughly accurate. Neither on the fourth whorl from the bottom nor anywhere else on the stem are there any cirri with fourteen joints, even where the terminal claw is included; though the regular decrease in the size of the cirri from above downwards is very striking, as pointed out by Sir Wyville.

ones just beneath the calyx. Throughout its whole length it tapers downwards from the calyx, rapidly at first, then more slowly and afterwards somewhat rapidly again, till the joints are but little larger than those of the most developed cirri on its middle part. The number of internodal joints also diminishes in this lower part of the stem; for while it reaches eleven or twelve in the middle of the stem, the numbers in the four lowest internodes are respectively nine, seven, five, five; and the remains of the cirri borne at the intervening nodes show a corresponding diminution in size. The inferior termination of the stem is not known, as it is broken at the syzygy beneath the lowest whorl of cirri.

The free mode of life appears to be attained in these individuals, not by actual fracture of the stem at a node so as to shorten it more or less, but by the lower and therefore older part remaining undeveloped, while new joints appear in succession above it, each growing to a larger size than those previously formed. The stem thus becomes slender and tapering, and but ill adapted for attaching itself below; but its length is not diminished so much as if it were broken at a node.

The downward tapering of the stem in some of the fossil Pelmatozoa has been already noticed; and it is evidently a character of more general occurrence than was suspected by Sir Wyville Thomson. Quenstedt[1] contrasts the comparatively short tapering stems of *Extracrinus briareus* with the gigantic ones of *Extracrinus subangularis*, which may reach the length of 50 or even of 70 feet; and he suggests that the former type and its allies "könnten gleichsam als eine Comatula betrachtet werden, deren Knopf zu grösserer Länge in einer Zeit heranwuchs, wo es noch keine eigentlichen Comateln gab." De Loriol[2] in like manner regards it as probable—"qu'ils avaient, à l'état adulte, une tige court, libre, et qu'à l'aide de leurs cirrhes tres nombreux et très longs ils pouvaient nager facilement et se transporter, rapidement peut-être, d'un lieu à un autre; ils avaient aussi la faculté de se fixer à quelque objet, lorsqu'ils en avaient le désir, au moyen des crochets dont est munie l'extrémité de leurs cirrhes."

I suspect, however, that the swimming was effected rather with the arms than with the cirri, which are not used for that purpose by the Comatulæ, and would have to be moved with considerable power in order to effect the locomotion of the animal. The condition of so many recent species is a strong argument in favour of the views formerly expressed by Buckland[3] and others regarding the possible locomotive powers of the Liassic Pentacrinidæ, though they have been somewhat discredited of late. Now too that their recent representatives have been found so abundantly in depths of less than 100 fathoms, instead of being exclusively abyssal types as was once supposed, the

[1] Encriniden, p. 271.
[2] Notice sur le Pentacrinus de Sennecey-le-Grand, Chalon-sur-Saone, 1878, p. 12.
[3] Geology and Mineralogy, vol. i. p. 437.

possibility of their becoming attached to floating timber does not seem so very distant after all. They may have been attached above by a slightly spreading base as on the modern telegraph cables; or, on the other hand, they may have been drifted in large numbers by the currents after detaching themselves from their original base of attachment.

Occupying the innermost part of the stem of a Pentacrinite, and lodged within its central canal, is its internal vascular axis (Pl. XXIV. figs. 1–5; Pl. LXII.). This consists of five peripheral vessels arranged around a central one. The former Pl. XXIV. figs. 2–5; Pl. LVIII. fig. 3—*ch'*) are downward extensions from the chambers of the quinquelocular organ within the calyx (Pl. XXIV. figs. 6–8; Pl. LVIII. figs. 1–3—*ch;* Pl. LXII.); while the latter (Pl. XXIV. figs. 2–5, *v.*) is similarly connected with the axial vessel or vessels of the chambered organ (Pl. XXIV. fig. 6; Pl. LVIII. figs. 1–3—*v.;* Pl. LXII.). This central vessel does not increase in size at the nodes, where the peripheral vessels expand considerably, so as to form a miniature chambered organ (Pl. XXIV. figs. 3, 4, *ch.n.*); and each chamber gives off one cirrus-vessel (fig. 4, *cv.*). The fibrillar sheath around the chambered organ in the calyx (Pl. XXIV. figs. 6, 7; Pl. LVIII. fig. 1—*ca;* Pl. LXII.) is continued down the stem, around its vascular axis (Pl. XXIV. figs. 1–5, *ca*; Pl. LVIII. fig. 3; Pl. LXII.). It is sometimes closely surrounded by a more or less complete ring of pigment masses, similar to those which occur in the surrounding tissue (Pl. XXIV. figs. 2, 5, *p.*); but in other parts of the same stem these are absent in the immediate neighbourhood of the central axis (figs. 3, 4). Radiating extensions of the latter are frequently to be seen (fig. 1. fig. 2, *ca'*). They proceed outwards into the organic basis of the skeleton, and then become lost, though they probably reach the epidermis, like the similar branches from the axial cords of the arms and pinnules, to which a nervous nature has long been attributed.

B. Bourgueticrinidæ.

The type of stem which occurs in this family differs in many respects from that characteristic of the Pentacrinidæ. The joints are very variable in their relative proportions, instead of being uniformly discoidal; they never form syzygial unions, but are freely movable upon one another, and are connected by successive pairs of ligamentous bundles instead of being strung, as it were, upon five tendons of variable length.

In the only two recent genera which belong to this family, *Bathycrinus* and *Rhizocrinus*, one or more of the young upper stem-joints are simple circular disks, with little or no markings of any kind upon their terminal faces (Pl. VII. figs. 1–3, 11; Pl. VIIa. fig. 3–6; Pl. VIIIa. fig. 1; Pl. IX. figs. 1–3; Pl. X. figs. 2, 9, 10; Pl. LIII. figs. 7, 8). But lower down the stem the joints become first cuboidal and then elongated, so that their length may be two or three times their diameter (Pl. VII. figs. 1, 10; Pl. VIIIa. figs. 2, 3; Pl. IX. figs, 1, 3; Pl. LIII. figs. 7, 8). The younger of these elongated joints are simply cylindrical; but the older ones are more dice-box shaped with

expanded ends, while the articular ridges in the long axes of the terminal faces cross one another at various angles.

This mode of articulation is common to all the Bourguetierinidæ, though the stem-joints are not always so long as in *Rhizocrinus* and *Bathycrinus*. It occurs also in the curious genus *Thiollericrinus* and in the stem of the larval *Comatula*. Both *Thiollericrinus* and *Bourgueticrinus* occur in the Jurassic rocks; while the same kind of column as occurs in these genera existed also in the Carboniferous *Platycrinus*, and according to Messrs. Wachsmuth and Springer[1] "forms one of the most characteristic features of the genus."

There is a considerable amount of variation among the different members of the Bourgueticrinidæ in the characters of the terminal faces of the stem-joints. In the Jurassic genus *Thiollericrinus*, in *Bourgueticrinus* (Jurassic and Cretaceous), and in the Cretaceous *Mesocrinus* the articular ridge is narrow and linear, expanding somewhat around the opening of the central canal to form the real articular surface.[2]

In all these genera a median groove extends along each half of the ridge, from the central opening towards the margin of the joint face; and short shallow branches proceed from it on either side so as to cut out the upper portion of the ridge into a double row of small teeth.

In *Thiollericrinus*, *Mesocrinus*, and *Bourgueticrinus ellipticus* the ligament-fossæ at the sides of the articular ridge are either uniformly shallow throughout their whole extent, or they are deepest in the immediate neighbourhood of the central canal. But they are completely separated from one another by the articular ridge, which is continuous from end to end of the elliptical surface. Very much the same is the case in the upper and middle stem-joints of *Bathycrinus* (Pl. VIIa. figs. 8, 9), except that the articular ridge is relatively larger and is destitute of teeth. But in the lowest stem-joints of this genus (Pl. VII. figs. 12, 13; Pl. VIIa. fig. 11), and in all parts of the stem of *Rhizocrinus* (Pl. X. figs. 11–14), the articular surface is incomplete, and instead of surrounding the central canal, is actually divided by it into two trihedral portions, the upper edges of which are toothed just like the corresponding parts of the complete ridge in *Bourgueticrinus ellipticus* or *Mesocrinus*. The two ligament-fossæ communicate with one another around the opening of the central canal, which thus appears to lie at the bottom of a deep depression. Quenstedt[3] figures some stem-joints of this kind from the white chalk of Rügen under the name of *Apiocrinus constrictus*.

[1] Revision of the Palæocrinoidea, part ii., *Proc. Acad. Nat. Sci. Philad.*, 1881, p. 69 (243).

[2] In a stem-joint from the Maestricht Chalk, which is figured by Quenstedt as *Apiocrinus* (*Bourgueticrinus*) *ellipticus* (Encriniden, Tab. 104, fig. 70), there is no articular ridge at all, but merely an oval articular surface around the opening of the central canal. Unless this be the result of an accidental removal of the ends of the articular ridge, it is a somewhat striking peculiarity which tends to approach the condition of the middle stem-joints in *Bathycrinus*, and has a still closer resemblance to a form of articular surface which is especially characteristic of the cirrus-joints (*ante*, pp. 7, 8).

[3] Encriniden, Tab. 104, figs. 64–66.

While the general characters of the stem are identical in *Rhizocrinus* and *Bathycrinus*, there is a good deal of variation in its details, and especially in the mode of growth.

In all cases the new joints are added at the top of the stem, immediately beneath the cup; but the rate at which they increase in length is very different in the different species. It appears from Sars's figures,[1] and from my own observations, that the production of new joints in the stem of *Rhizocrinus lofotensis* is slow compared to their subsequent increase in length. For there are very rarely more than three joints beneath the cup which are wider than high, and even these have an appreciable thickness (Pl. IX. figs. 1, 2; Pl. X. fig. 1). Sars remarks of the uppermost one that it is "annulaire et a 2 ou 3 et même souvent 5 ou 6 fois plus de largeur que de hauteur;" while there are usually not more than eight cylindrical joints beneath it. Below this limit the joints have the well-known dice-box shape, with the characteristic terminal faces, the peculiarities of which begin to appear very few joints below the cup.

Most individuals of *Rhizocrinus rawsoni* seem to be generally similar to *Rhizocrinus lofotensis* in these characters (Pl. IX. fig. 3; Pl. LIII. figs. 7, 8). But in one example I found five joints beneath the cup which were wider than high. The second and third are mere circular disks with perfectly plain faces like those of the fourth (Pl. X. fig. 10); and the faces of the newly formed joints of *Rhizocrinus lofotensis* which are figured by Sars[2] are of the same nature. But the uppermost joint of all is of a different character altogether (Pl. X. fig. 9). It has a pentagonal outline, and its surface, which rises gradually from the circumference towards the centre, is divided by five radiating ridges into an equal number of trapezoidal fossæ that receive the lower ends of the elongated basals (Pl. X. figs. 3, 5). Here, therefore, we find the top stem-joint presenting the same characters that it does in *Apiocrinus*[3] and *Millericrinus*,[4] and entering to some extent into the composition of the cup, while the new joints are probably intercalated below it. Quenstedt[5] speaks of this uppermost stem-joint in the Apiocrinidæ indifferently as "Endstück, Endsäulenglied, or Fünfrippenglied." De Loriol[6] has named it "article basal;" while Zittel[7] speaks of it as the "Centro-dorsal," and remarks "Dasselbe scheint, wie aus der Andeutung von Nähten hervorgeht, aus 5 ursprünglich getrennten Stücken entstanden zu sein und entspricht wahrscheinlich den 5 Infrabasalplättchen bei *Encrinus*." It is perhaps a little inexpedient to employ the term "centro-dorsal" for a joint which bears no cirri, as its similarly named homologue does in the Comatulæ.

[1] Mémoires pour servir à la connaissance des Crinoïdes vivants. 1. Du *Rhizocrinus lofotensis*, tab. i., ii.

[2] *Op. cit.*, tab. ii., figs. 20–22.

[3] D'Orbigny, Histoire Naturelle, générale et particulière des Crinoïdes vivans et fossiles., pl. ii. fig. 3, pl. iii. fig. 4, pl. v. fig. 4.

[4] *Ibid.*, pl. xiv. figs. 15, 23, 24; and *Quart. Journ. Geol. Soc.*, vol. xxxviii. p. 33, pl. i.

[5] Encriniden, pp. 314, 315.

[6] Swiss Crinoids, p. 4; Paléont. Franç., *loc. cit.*, p. 19.

[7] Handbuch der Palæontologie. Palæozoologie, Bd. i., pp. 388–390.

But I should prefer doing this to using a name, as de Loriol has done, which is so very similar to that universally employed to designate some of the calyx plates, although there is no sort of homology between the two structures. This latter point is recognised by de Loriol, who makes it clear that he regards the "article basal" as a stem-joint.

Whatever may be the case in *Apiocrinus*, this plate is single in *Rhizocrinus rawsoni* (Pl. X. fig. 9), and I cannot help suspecting that Zittel has been misled by the appearance of sutures into regarding it as probably consisting of five coalesced under-basals. I have noted a somewhat similar condition in *Millericrinus pratti*.[1]

Owing to the larger number of discoidal joints in the stem of *Rhizocrinus rawsoni* than in that of *Rhizocrinus lofotensis*, the gradual development of their articular faces is more easily made out in the former species. As the joints become longer than wide, shallow fossæ appear to the right and left of the opening of the central canal, which thus seems to be the deep middle portion of an oval depression occupying the shorter axis of the elliptical face (Pl. X. fig. 12). These fossæ gradually increase in relative size, and encroach more and more upon the original plane surface of the joint face, still, however, remaining in connection with one another around the central canal (Pl. X. figs. 11, 13, 14). They reach nearly to the margin of the joint face, so as to leave a small articular rim outside them; but they do not reach so far in the direction of the long axis, at the ends of which the original surface of the joint remains to form the so-called "articular ridge." This is, however, by no means continuous across the opening of the central canal, as is implied by its name; for it is merely represented by two triangular surfaces which encroach upon the original oval depression so that it assumes the form of a rather short-handled dumb-bell (Pl. X. figs. 11, 13, 14). The two ends slope rapidly downwards towards the centre, where the opening of the axial canal is situated. It thus establishes a connection between the two fossæ and interrupts the continuity of the articular ridge.

This type of joint-face also occurs in the lowest part of the stem of *Bathycrinus* (Pl. VIIa. figs. 10, 11), but it is the result of a different mode of growth altogether. There are several thin discoidal joints at the top of the stem (Pl. VII. figs. 1–3, 11; Pl. VIIIa. fig. 1), and the uppermost one, on which the basals rest, has its surface marked by a ten-rayed depression which extends outwards from the five-lobed opening of the central canal (Pl. VIIa. fig. 3). The corresponding face of the basal ring is marked in the same manner (figs. 13, 14); and the fossæ lodge the five horse-shoe shaped ligamentous bundles which unite the basals to the stem-joints below them. On the upper face of the second joint, however, the opening of the central canal is surrounded by a raised articular rim, still showing traces of fossæ like those on the top joint, and this rim is more marked on the next few joints (figs. 4, 5). As the joints below become thicker and their terminal faces more oval, the articular rim also

[1] On some new or little known Jurassic Crinoids, *Quart. Journ. Geol. Soc.*, vol. xxxviii. p. 34.

assumes an oval form, and the ten markings on its edge first become arranged into two groups of five each (fig. 5), and then finally disappear (fig. 6). This is due to the five ligamentous bundles mentioned above as being attached to the basals, becoming gradually replaced by the two larger and somewhat crescentic bundles which unite the joints lower down the stem. The articular rim eventually becomes restricted to a broad ridge which occupies the short axis of the oval oblong face, and is pierced in the centre by the oval opening of the central canal (figs. 7, 8). In the slender joints of the upper third of the stem (fig. 7) this ridge takes up the greater part of the articular surface, and there is merely a shallow fossa on either side of it. As the joints increase in stoutness the ridge becomes relatively narrower, and the lateral fossæ proportionately larger (figs. 8, 9). They are shallowest at the edge, and gradually deepen as they approach the ridge. When the joints begin to shorten again but continue to increase in stoutness, their terminal faces become more circular (fig. 10), though the planes of the articular ridges at the two ends of each joint still continue to cross one another. The ridges themselves still diminish in relative width, and become somewhat constricted in the middle, until there is only a very narrow rim around the opening of the central canal (figs. 9, 10). Lower down the stem this rim disappears altogether (Pl. VII. figs. 12, 13; Pl. VIIa. fig. 11), so that the two lateral fossæ communicate around the central opening just as in *Rhizocrinus* (Pl. X. figs. 11–14).

The joint-faces also become oval again, and the articular ridges now occupy their longer axis (Pl. VIIa. fig. 11) instead of the shorter ones, as is the case at the top of the stem (figs. 7–9). The two halves of each ridge which are separated by the opening of the central canal are of an elongated triangular shape, and relatively narrower than in *Rhizocrinus rawsoni*, owing to the greater size of the lateral fossæ. Each is denticulate along its median line, as in the other Bourgueticrinidæ.

The distinction of the lower stem-joints of *Rhizocrinus* and *Bathycrinus* thus becomes a matter of some difficulty, though those of the upper and middle parts of the stem are very different in their characters.

In the young individuals of both genera most of the stem-joints are simple, more or less elongated cylinders; and the characteristic dice-box shape is only visible in a few joints immediately above the root (Pl. VIIIa. figs. 2, 3; Pl. LIII. figs. 7, 8; woodcut, fig. 16, p. 244).

The lower part of the stem in the Bourgueticrinidæ may bear a large number of irregularly branched radicular cirri, two or more proceeding from each joint near the end of the long axis of one face (Pl. IX. fig. 1; Pl. X. figs. 13, 15); while the main axis may eventually break up into a similar set of branching rootlets. These two forms of roots may coexist in the same individual, or either may occur alone. In some specimens of *Rhizocrinus lofotensis* the radicular cirri are exceedingly abundant. Thus in an indivi-

dual figured by Sars[1] they occur on the lowest thirty-three joints of a stem with fifty-nine joints altogether. In another case five out of eighteen joints are cirriferous; while the individual represented in Pl. IX. fig. 1 has only nine cirriferous joints in a stem of over forty. A similar variation occurs in *Rhizocrinus rawsoni*. Every joint in the lowest part of the stem may bear cirri at one or both ends of the long axis of its upper face. But I have in no case found more than fifteen joints in this condition, and they are sometimes not consecutive, a cirrus-less joint being occasionally interposed between two others which bear cirri (Pl. X. fig. 15). On the other hand, in the only individual with a complete stem which was obtained by the Challenger, and also in the young specimens dredged by the "Porcupine," there are no radicular cirri at all, but only a spreading root formed by subdivision of the main axis of the stem (Pl. LIII. fig. 7); and this appears to be a constant condition in *Bathycrinus* (Pl. VII. figs. 1, 9; Pl. VIIIa. fig. 3).

Below the last of the regular and dice-box shaped joints, which may or may not bear cirri, there come one or more others of irregular shape and variable size. Spreading rootlets proceed outwards from these, as a rule more abundantly in *Rhizocrinus* than in *Bathycrinus*. In *Rhizocrinus lofotensis* this inferior joint usually bears several slender root filaments disposed around a central one; while one or two stronger and branching rootlets sometimes come off between it and the regular stem-joints. This is more especially the case in *Rhizocrinus rawsoni*; but in *Bathycrinus* the inferior joint, or "root-joint" as it has been called, is quite short, and gives off two or rarely three chief roots, which themselves subdivide into smaller ones (Pl. VII. figs. 1, 9; Pl. VIIIa. fig. 3).

Both these rootlets of the stem-axis itself and the radicular cirri are composed of a series of gradually diminishing joints closely united by ligaments. They attach themselves to foreign bodies by calcareous expansions round their ends or beneath the sides on which they happen to rest (Pl. IX. fig. 1; Pl. X. fig. 15). Anything serves for this purpose which may improve the anchorage of the Crinoid in the soft mud, which is nearly universal at great depths, *e.g.*, fragments of shell, grains of sand, sponge-spicules, foraminiferal tests, &c. Hence, whatever be the case in the Pentacrinidæ, *Rhizocrinus* and *Bathycrinus* must remain permanently fixed in one place throughout life.

In a specimen of *Rhizocrinus rawsoni* which was dredged by the "Travailleur," and was described as a new genus *Democrinus* by Perrier,[2] the diameter of the stem is lessened at the origin of two groups of rootlets, and regains its former size lower down. Perrier suggests the question "si la partie qui se prolonge au delà des racines n'est pas destinée à devenir un second pédoncule surmonté d'un second calice. Si cette induction se vérifie, les *Democrinus* constitueront le premier exemple actuel d'Échinodermes vivant en

[1] *Op. cit.*, tab. i. fig. 1.

[2] Sur un nouveau Crinoïde fixé, le Democrinus Parfaiti, provenant des dragages du "Travailleur," Comptes rendus, t. xcvi., No. 7, pp. 450, 451.

colonies et ramifiés." I can, however, see no probability whatever in this supposition, having met with no facts confirmatory of it either in any of the numerous roots of *Rhizocrinus* and *Bathycrinus* which I have examined, or in the descriptions of these genera by Sars and Danielssen. Neither is it supported in the slightest degree by what we know of the embryology of the Crinoids.

Prof. Perrier has suggested some further views of the morphology of the stem which I find myself unable to accept. He begins by saying "De tous les Crinoïdes fixés actuels, les *Democrinus* sont ceux chez qui les dimensions transversales du calice sont le plus foibles par rapport au diamètre du pédoncule."

I am indebted to his kindness for the following measurements of his specimens—

Length of the calyx from the terminal furrow to the top stem-joint, . .	9 mm.
Maximum diameter of the calyx, ...	2 „
Diameter of the stem-joints, ...	1 „

That is to say, the diameter of the calyx does not exceed twice that of the stem-joints. But at the time Prof. Perrier made the statement quoted above he had before him the following measurements of the calyx and stem in three varieties of *Rhizocrinus rawsoni*—

	Basal tube.	Stem-joints diameter.
1. Blake, ...	5·5 × 2·50 mm.	2·25 mm.
2. Challenger, . . .	5·0 × 2·00 „	2·00 „
3. Porcupine, . . .	3·0 × 1·75 „	1·25 „

Hence the maximum width of the calyx in the Challenger specimens of *Rhizocrinus rawsoni* is the same as that of the largest stem-joints; while the proportion is as 2 : 1 in the so-called *Democrinus*, and this is not attained by the calyx, either of the "Blake" or of the "Porcupine" specimens. It seems to me that the calyx of *Democrinus* is larger relatively to the stem than in any of the Crinoids most nearly allied to it (instead of being narrow as stated by Prof. Perrier), who proceeds as follows:—"Si l'on songe que, chez les Échinodermes libres actuels, le corps tout entier ne représente que le calice des Crinoïdes fixés surmonté de ses bras, on est étonné de voir une partie qui est absolument nulle chez les représentants des autres groupes prendre chez les *Democrinus* un développement tel qu'elle représente cinq à six fois au moins le volume du corps proprement dit. Ce fait seul nous avertit que le pédoncule doit être pris en grande considération pour la détermination de la forme fondamentale des Échinodermes. Chez les *Democrinus*, il produit un appareil radiculaire formé de rameaux articulés ramifiés ayant la même structure que lui-même et présentant des dimensions supérieures à celles des bras; cet appareil ne saurait être davantage négligé au point de vue morphologique, et l'on est conduit à considérer ses diverses branches comme ayant la même valeur que le pédoncule lui-même dont elles ont la structure."

A far better instance than *Democrinus* of disproportion between stem and head is

furnished by the Liassic *Extracrinus*, the stem of *Extracrinus subangularis* reaching a length of 50 to 70 feet. But even as regards *Democrinus* I cannot admit that the dimensions of the stem are so much greater than those of the arms. This may indeed be the case in Perrier's three specimens, of which "deux sont totalement dépourvus de bras; le troisiéme n'en présente que des restes très courts, d'après lesquels il est aisé de voir que les bras devaient être extrèmement peu développés." But in the Carribbean examples of *Rhizocrinus rawsoni* the longest stem (180 mm.) contains sixty-eight joints above the root, while there are five arms, each consisting of about eighty joints. Nearly half of these bear pinnules, so that even if the radicular part of the stem is taken into account, the superior dimensions would seem to be on the side of the arms rather than on that of the stem, which Perrier considers to represent five or six times the volume of the calyx and arms together.

It is likely enough that this may have been true in his three specimens of *Democrinus*, which had lost the whole or greater part of their arms, owing to fracture at the syzygies, as is only too often the case with both species of *Rhizocrinus*. But when a tolerably perfect individual is obtained the arms are found to be considerably more than "extrèmement peu développés," as was so easily inferred by Perrier upon totally insufficient evidence. He goes on to say, "Alors même qu'ils ne vivraient pas en colonie, le volume considérable de leurs racines ramifiées, la ressemblance de ces racines avec les bras qui surmontent le calice et dont elles sont probablement homologues, suffisent à démontrer que la disposition arborescente des parties, préface en quelque sorte de la symmétrie radiaire, n'est pas plus étrangère au type des Échinodermes qu'au type des Cœlentérés."

The relationship of the Echinoderms to the Cœlenterates need not be discussed here; but the resemblance and "probable homology" which Prof. Perrier sees between the arms and the root of a Crinoid appear to me to be forced in the extreme. The arms are merely extensions of the body, containing the same nerves, vessels, and body-cavity as are found in the calyx, together with the fully developed genital glands which are usually sterile in the body. But the branches of the root have the same structure as the stem, as remarked by Perrier himself; and this is very different from that of the cup and arms. It is true that the rootlets, like the arms, are traversed by axial cords which are connected with the fibrillar envelope of the chambered organ; but there the resemblance ends. They support no soft parts as the joints of the arms and pinnules do; and being formed entirely on the right antimer are totally devoid of any of the ambulacral structures which are so important in the morphology of the arms. If the term "homologous" is to be employed for a mere superficial resemblance of this kind, a new word must be introduced to denote community of origin and morphological similarity. One might almost as reasonably say that the quills on the back of a porcupine are homologous with its limbs.

Both in *Bathycrinus* and in *Rhizocrinus* the organic and calcareous networks, which interpenetrate one another, are not always perfectly continuous throughout the substance of the stem-joints. For both in optical and in transverse sections of decalcified stems empty spaces are often visible, especially in the immediate neighbourhood of the central axis. Five of these spaces appear in some of my transverse sections of the lower stem-joints of *Bathycrinus* (Pl. VIIa. fig. 2, *rs*). They are radially disposed, being situated immediately outside the five peripheral vessels of the central axis (*ch'*), which they may not greatly exceed in size. Both spaces and vessels may contain larger or smaller masses of pigment granules (*p*). The walls of the former are less well-defined than those of the latter, but are distinctly sharper than the outlines of the spaces in the organic plexus forming the remainder of the stem-joint.

It sometimes happens in the lower part of the stem that one of these spaces may increase very greatly in size, and so displace the central axis from its median position; or the space may approach quite near to the surface of the joint. They are much more irregular in the lower part of the stem than in the uppermost elongated joints, where they are also of larger relative size (Pl. VIIa. fig. 1, *rs*); and they appear to communicate with one another from joint to joint, through the elongated oval opening of the central canal (Pl. VIIa. fig. 7). But there is nothing to be seen of them in the discoidal joints at the upper part of the stem, which are continuously traversed by closely set ligamentous fibres (Pl. VIIb. fig. 1). The best preparations that I have been able to obtain illustrative of this point have been from the stem of *Bathycrinus;* but I have also seen these spaces, though not so well, in *Rhizocrinus*. The former genus (or at any rate *Bathycrinus aldrichianus*) is remarkable for the abundance of delicate fibrils which may be seen proceeding outwards from the central fibrillar axis of the stem, the nervous nature of which is gradually coming to be recognised. Some of the larger of these fibrils are shown in optical section in Pl. VIIa. fig. 1, *ca'*. But a much larger number of smaller ones may be seen with a high power. They leave the central axis in a more or less transverse direction, and form an open plexus, immediately beneath the external surface of the stem. This is most distinctly seen over the radial spaces, where the decalcified stem is, of course, more transparent than elsewhere. It is noteworthy that the arms of *Bathycrinus aldrichianus*, like the stem, are also remarkable for the large number of branches which proceed outwards from their axial cords (Pl. VIIb. figs. 6, 7; Pl. VIIIa. figs. 4, 5—*a'*). The corresponding branches in the stem of *Pentacrinus* have been already noticed (*ante*, p. 23).

C. Hyocrinidæ.

The stem of *Hyocrinus* is one of considerable interest, because it is the only recent Crinoid in which the terminal faces of the stem-joints are of the same nature as those of

the Apiocrinidæ and of so many of the Palæocrinoids. The applied surfaces of the cylindrical joints, forming the lowest portion of the stem with which we are acquainted, were described by Sir Wyville Thomson[1] as "being marked with a pattern of radiating grooves and ridges." There appears, however, to be a good deal of variation in this respect; for, while some of the joint-faces have the radiating pattern very well developed, others are perfectly plain (Pl. Vc. fig. 4), and others have only slight indications of the striation. But the radiating striæ never "resemble minute pores penetrating the walls," as stated by Wachsmuth and Springer,[2] of the similarly marked joint-faces in the Palæocrinoids.

The stem of *Hyocrinus* is much more rigid than that of the Bourgueticrinidæ. The short cylindrical joints are united by uniformly disposed ligaments (Pl. Vc. fig. 5, *ls*), the fibres of which are all of equal length and not longest in the centre as in the oldest parts of the stem of *Bathycrinus* and *Rhizocrinus*. The ligamentous fibres at each end of the joint extend into its substance for about one-fifth of its length, so that the calcareous tissue is closer towards the ends than in the median parts of the joints. These contain radial spaces (Pl. Vc. fig. 5, *rs*) of the same nature as those just described in the Bourgueticrinidæ (Pl. VIIa. figs. 1, 2, *rs*).

So far as I can make out from the only two fragments of stem which have reached me, measuring 70 and 85 mm. respectively, there are a large number of discoidal joints at the top of the stem (Pl. VI. figs. 1–3). Their thickness gradually increases from above downwards, until they are about half as long again as wide. The length then diminishes again and the width increases, rising in one example from 1 mm. to nearly 1·5 mm. within twelve joints. The lower joints thus become more discoidal again, like those some little way below the calyx. What they were in the stem-fragment, 170 mm. long, which is mentioned by Sir Wyville Thomson, I have no means of knowing. Neither are we acquainted with the nature of the actual base of attachment.

[1] *Journ. Linn. Soc. Lond.* (Zool.), vol. xiii. p. 52, 1878.

[2] Revision, part i. p. 14.

III.—THE CALYX.

In all the recent Crinoids, with the single exception of *Thaumatocrinus* (Pl. LVI. figs. 1–4), the calyx proper is formed of but two series of plates, viz., the basals, which rest upon the top stem-joints, and the radials, which are supported by and alternate with the basals. The plates of these two series are suturally united to their fellows and to one another; and they enclose a central cavity which is sometimes large enough to contain the whole visceral mass, as in *Holopus* (Pls. I.–IV.) and *Hyocrinus* (Pl. VI.). In other cases, however, the internal cavity of the calyx is reduced to a minimum, and it lodges nothing but the chambered organ with the plexiform gland which rises from it; while the entire visceral mass is situated altogether above it, and is very easily detached from it, as in many Comatulæ, so that there can hardly be said to be any cup at all.

Intermediate conditions between these two extremes are met with in the Bourgueticrinidæ and Pentacrinidæ. In the last named family the cup which is formed by the united upper surfaces of the radials is wider than in *Antedon*, but somewhat more hollowed than in *Actinometra* (Pl. XII. figs. 1, 2, 15, 16; Pl. XVIII. figs. 4, 5; Pl. XX. figs. 5, 8; Pl. XXVI. fig. 11; Pl. XXX. figs. 3, 4; Pl. XXXIII. fig. 5; Pl. XXXIV. figs. 7, 8; Pl. L. figs. 5, 6); and the lowest portion of the visceral mass rests in this concave upper surface of the radial pentagon; while the greater part of it lies in the cup which is formed by the outer radials and lowest distichals (Pl. XVII. fig. 5; Pl. L. fig. 1; Pl. LXII.). But the central funnel of the calyx, which is between the inner faces of the radials, only contains the plexiform gland ascending from the chambered organ (Pl. LVIII. fig. 3, *x*).

This is also the case in *Rhizocrinus* and *Bathycrinus* (Pl. VIIb. figs. 1, 4, 5, *x*). In the former genus the upper surface of the calyx has a deep hollow which lodges a portion of the intestinal coil (Pl. X. figs. 1, 4, 6, 7, 8); while the upper part of the visceral mass is entirely supported by the first four brachials in two syzygial pairs (Pl. X. figs. 2, 20). In *Bathycrinus*, however, the gut hardly descends to the level of the first radials; and though the visceral mass is very largely supported by the large wing-like processes of the axillaries, it is practically quite free from the lowest brachials (Pl. VII. fig. 3; Pl. VIIb. figs. 1, 7, 8).

Concealed in the lower portion of the calyx is the chambered organ, the position of which, relatively to the calyx-plates, varies considerably. In all the Comatulæ it is lodged within the cavity of the centro-dorsal, and it is therefore entirely on the dorsal side both of the radials and of the basals, whether the latter have been metamorphosed into a rosette or not. But in the stalked Crinoids there is no enlargement of the central canal of the stem within its uppermost joint, and the vascular axis passes up into the calyx before expanding to form the chambered organ. In *Rhizocrinus*, *Bathycrinus*, and

Pentacrinus this expansion takes place near the top of, but entirely within the basal ring, the radials having no share in the protection of the chambered organ, though they surround the lowest portion of the plexiform gland which rises out of it (Pl. VIIb. figs. 1, 4, 5; Pl. VIIIa. figs 6, 7; Pl. XXIV. figs. 7–9; Pl. LVIII. figs. 1–3; Pl. LXII.). Within this central funnel of the radials, and closely enveloping the plexiform gland, is a kind of plug formed by numerous irregular limestone bars which are developed from the inner faces of the radials. In *Bathycrinus* it is practically little more than calcified connective tissue (Pl. VIIb. figs. 1, 4, 5, *c*), but it becomes very solid in *Rhizocrinus*, and has been wrongly described as a basal rosette (Pl. VIIa. fig. 7; Pl. X. figs. 1, 4, *br.*). It is also well developed in *Pentacrinus* (Pl. XXIV. figs. 8, 9, *rp.*), and is lodged in a small depression upon the upper surface of the basal ring, which is formed by the truncation of the inner ends of its component pieces (Pl. XX. figs. 2–6, 9).

Among the Apiocrinidæ the cavity which lodged the chambered organ is bounded in varying proportions by the basals and radials. In some species, such as *Millericrinus milleri*, this structure must have lain altogether upon the ventral aspect of the basals. These form a complete ring, just as in the aberrant Comatulæ, *Atelecrinus* and *Thaumatocrinus;* but in both these types the basal ring is on the ventral side of the chambered organ, which is precisely the opposite condition to that of *Millericrinus milleri*.

A. The Basals.

The basals of the Neocrinoidea vary considerably in the extent to which they are developed. In all the Palæocrinoids the radials are separated from the top stem-joint by one complete ring of plates, to which a second is often added. But in the Neocrinoids no basals may be visible at all upon the exterior of the calyx, as in most Comatulæ; or there may be a single complete ring of high plates as in *Rhizocrinus* (Pl. IX. figs. 1–3; Pl. X. figs. 2, 3; Pl. LIII. figs. 7, 8); or there may be two rows of plates of variable size as in *Encrinus*, *Extracrinus*, and *Marsupites*.

The absence of external basals in most recent Comatulæ is due to their having undergone metamorphosis into the well-known rosette, which is concealed between the centro-dorsal and the radials. But the occurrence of this condition in a stalked Crinoid would appear somewhat improbable. Personal examination has convinced me that in two cases[1] at any rate the supposed absence of basals in fossil Pentacrinidæ is merely the result of defective observations; but this may not be invariably true. No basals are visible externally in the Jurassic *Isocrinus pendulus*, Meyer,[2] nor in the *Pentacrinus pentagonalis personatus* from the Brown Jura, which is figured by Quenstedt[3] without

[1] These are (1) *Pentacrinus fisheri*, Forbes, from the Kimmeridge Clay of Weymouth; and (2) a fine specimen from the Chalk, which is figured in Dixon's Geology of Sussex (1878 edition, pl. xix. 22).

[2] Isocrinus und Chelocrinus, Museum Senckenbergianum, Frankfurt, 1837, Taf. xvi. figs. 1, 2.

[3] Encriniden, Tab. 98, fig. 137.

any notice of its peculiarities. They likewise appear to be absent in the Forest-Marble specimen from Farley in Wiltshire, which was described by Goldfuss as *Pentacrinus scalaris*;[1] while they are certainly absent externally in one of the two known specimens of *Metacrinus costatus*, though fully developed in the other (Pl. XLIX. figs. 1, 2). This is a most curious anomaly; but as the specimen cannot be sacrificed to investigation, it is impossible to ascertain whether the basals are absent entirely, or whether they have been metamorphosed into a rosette.

It is possible that they are so greatly reduced in size as to fail to appear externally, as occasionally happens in *Encrinus* and in the fossil Comatulæ, which retain their embryonic basals in an unmetamorphosed condition.[2] They are sometimes quite small and insignificant in comparison with the radials, as in the Liassic *Pentacrinus tuberculatus*, and in some varieties of the recent *Pentacrinus decorus* (Pls. XXXIV.–XXXVI.). In these and similar forms they appear at the lower angles of the calyx as minute rounded plates, between which the lower edges of the radials rest directly upon the top stem-joints. The basals are therefore only in contact with one another by their inner ends (Pl. XXXIV. fig. 8). But in other species, both recent and fossil, they are considerably larger, and their outer ends separate the radials more completely from the top stem-joint (Pl. XIII. fig. 1; Pl. XV. fig. 2); while the union of their inner ends is more extensive Pl. XII. fig. 16; Pl. XXVI. fig. 11). In fact all degrees of union may be traced (both in different species and in different individuals of the same species) from the condition of *Pentacrinus blakei* and *Pentacrinus decorus* (Pls. XXXI., XXXV.) to that of *Pentacrinus wyville-thomsoni* and *Pentacrinus maclearanus*, in which the radials are separated from the top stem-joint by a ring of large and closely-united basals (Pls. XVI., XIX. figs. 1, 6, 7). The genus *Cainocrinus* of Edward Forbes has been lately revived by de Loriol[3] for a few fossil species which possess a closed basal ring, but are not otherwise different from *Pentacrinus*. The condition of the recent Pentacrinidæ, however, is such as to entirely preclude the possibility of employing this very variable character as a generic distinction.

A similar series of gradations is to be met with among the fossil Comatulæ, in which group there appears to be much more individual variation than among the Pentacrinidæ. In some few species no basals are visible externally at all. In others, the outer ends of small prismatic rods may appear at some angles of the calyx but not at others, while their inner ends do not meet at all or only very slightly so. In some species again, the outer ends of the basal rods are smaller than the inner ends, which meet together and entirely separate the median portion of the radial pentagon from the centro-dorsal beneath. Lastly, in a chalk *Comatula* mentioned by Schlüter[4]

[1] Petrefacta Germaniæ, vol. i. pl. lx. fig. 10.

[2] On the genus Solanocrinus, Goldfuss, and its Relations to recent Comatulæ, *Journ. Linn. Soc. Lond. Zool.*, vol. xv. pp. 211, 212.

[3] Swiss Fossil Crinoids, pp. 111, 112.

Ueber einige astylide Crinoiden, *Zeitschr. d. deutsch. geol. Gesellsch.*, 1878, p. 66.

there is a complete ring of united basals as in the recent genera *Atelecrinus* and *Thaumatocrinus* (Pl. LVI. figs. 1–4). In the four other genera of recent Comatulidæ, however, the primary embryonic basals undergo transformation into the well-known rosette, which is really a secondary structure. It lies over the chambered organ, between the under surface of the radial pentagon and the upper face of the centro-dorsal; but it is entirely concealed, and does not appear at all upon the exterior of the calyx.

In many Comatulæ more or less prismatic rods proceed outwards from the interradial angles of the rosette, and their ends are often visible on the exterior of the calyx. They occupy exactly the same positions as the rod-like basals of many fossil Comatulæ, but do not represent them morphologically, for they are not developed from the primary embryonic basals. These last become transformed into the rosette, which is a secondary structure as shown by Dr. Carpenter;[1] while the tertiary basals which are connected with its interradial angles are merely ossifications in the connective tissue of the synostosis between the radials and the centro-dorsal, and are somewhat variable in their development.[2] They do not occur in *Antedon rosacea*, nor in the species on both sides of the Atlantic which are most nearly allied to it, viz., *Antedon phalangium*, *Antedon dentata*, *Antedon hageni*, &c.; and they seem to be absent in *Eudiocrinus*, at any rate in *Eudiocrinus semperi*. But they reach a relatively large size in many tropical species both of *Antedon* and of *Actinometra*, in which latter genus I have never found them to be absent, and they also occur in *Promachocrinus* (see fig. 1, A on p. 37). [See Note B.]

B. The Radials.

There is considerable variation in the degree of lateral union between the individual basals and radials of stalked Crinoids. Those of *Holopus* (Pls. I.–IV.) are so intimately fused that the sutures are entirely invisible on the exterior of the tubular calyx. In *Hyocrinus* (Pl. VI.) the interradial sutures are quite evident, but those between the basals are very obscure. In *Rhizocrinus*, and especially in *Rhizocrinus lofotensis*, the sutures between the basals are usually entirely invisible, not only externally but also in transverse sections of the decalcified calyx; while the basiradial and interradial sutures are merely indicated by very faint lines on the surface of the cup (Pl. IX. figs. 1, 2); and strong measures are necessary before the individual joints will separate from one another. In the Pentacrinidæ and Comatulidæ the union between the radials is less close and the sutures well defined, while the condition of the basals varies according to circumstances (Pl. XIII. fig. 1; Pl. XV. figs. 1, 2; Pl. XVI.; Pl. XX.; Pl. XXXIII. figs. 8–10; Pls. XXXV.–XXXVII.; Pl. XXXIX.; Pl. XLIII.). The union of the

[1] *Phil. Trans.*, 1866, pp. 744, 745.

[2] The genus Actinometra, *Trans. Linn. Soc. Lond.* (Zool.), vol. ii. pp. 93–105; and the genus Solanocrinus, *Journ. Linn. Soc. Lond.* (Zool.), vol. xv., 1880, pp. 212–214.

basals of *Bathycrinus* is extremely close, and in old individuals no sutures are visible externally (Pl. VII. figs. 1, 2, 11; Pl. VIIa. figs. 12–14), though they appear in transverse section (Pl. VIIb. fig. 2) and also in young examples. I have never succeeded, however, in separating the plates from one another by the usual methods.

The radials of *Bathycrinus*, on the other hand, are much less closely united. They are thin plates in contact with one another by quite narrow sides (Pl. VII. figs. 6, 6*a*). Those of *Bathycrinus aldrichianus* were described by Sir Wyville Thomson as being "often free; but in old examples they also are frequently anchylosed into a funnel-shaped piece."[1] All the specimens which I have examined are in the latter condition, though the plates are readily separable. But I do not think it possible that they could ever be perfectly free as the other two radials are; and I have always found them to be closely united by ligaments up to the level of the circular commissure (Pl. VIIb. fig. 4, *l*), though they become much more free near the top of the calyx (Pl. VIIb. fig. 5). The

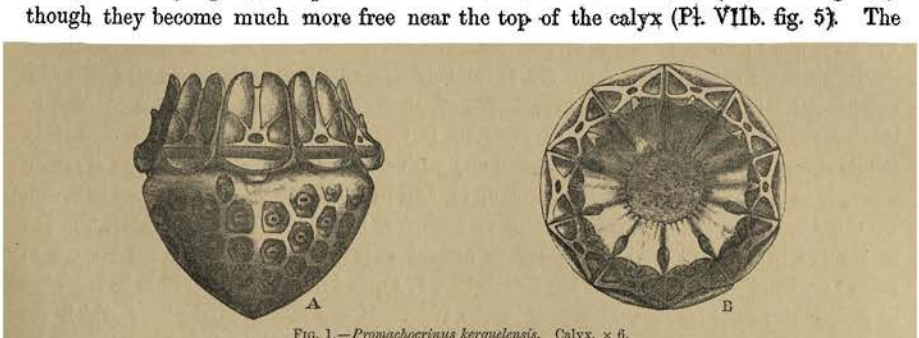


FIG. 1.—*Promachocrinus kerguelensis*. Calyx, × 6.

A. Side view, showing the alternation of the five primary radials with the five others, which are separated from the centrodorsal by the rays of the basal star. B. Upper view, showing the interior of the central funnel formed by the radials.

difference between the "free" and the "anchylosed" conditions is probably only due to variations in the extent to which limestone is deposited around the fibres of the above mentioned interradial ligaments.

The difference between the basal and radial rings in the amount of lateral union (*i.e.*, in the distinctness of the sutures) between their component joints, which is more or less evident in *Hyocrinus*, *Bathycrinus*, and *Rhizocrinus*, appears also in some fossil Crinoids. Beyrich has pointed out[2] that in young individuals of *Encrinus gracilis* the sutures between the basals are invisible, although those between the radials are distinct enough; and the same character has been noticed by Mr. R. Etheridge, jun., and myself as occurring in the Palæozoic *Allagecrinus austini*.[3]

[1] *Journ. Linn. Soc. Lond.* (Zool.), vol. xvi. p. 50.

[2] Ueber die Crinoiden des Muschelkalks, Berlin, 1857, p. 44.

[3] On Allagecrinus, the representative of a new family from the Carboniferous Limestone Series of Scotland, *Ann. and Mag. Nat. Hist.*, ser. 5, 1881, vol. vii. pp. 285–288.

The second brachials of *Rhizocrinus* (Pl. VIIIa. fig. 8, B_2), and the second radials of *Bathycrinus* (Pl. VIIb. fig. 6, R_2) are in contact by their lower edges, but soon become entirely free from one another (Pl. VII.; Pl. VIII. figs. 1, 2; Pl. IX. figs. 1–3; Pl. X. figs. 1, 2, 6–8); while the corresponding plates in *Hyocrinus* (Pl. VI.) are absolutely free. But in many Crinoids the second radials are often very closely united by ligamentous bundles. These are lodged in fossæ at the sides of the proximal face which is not quite so wide as the distal one (Pl. XII. figs. 9, 10; Pl. XXI. figs. 5*a*, 5*c*). The first joints beyond every axillary are more or less closely united in the same way (Pl. XXI. figs. 3*b*, 4*b*). But the second joints and the axillaries themselves are free, though often in very close contact with their neighbours, so that their apposed sides are more or less flattened (Pl. XXI. figs. 1*b*, 2*b*); and in some cases the first four or five of the free brachials have their sides flattened in this way, where they come in contact with one another and with the corresponding joints of adjacent rays (Pl. XV. fig. 2; Pl. XVI. fig. 1; Pl. XXXa. fig. 8).

In all the Pentacrinidæ there are invariably five rays. I have never met with any exception to this rule, and all the specimens of *Bathycrinus* that I have seen conform to it also. The original specimen of *Holopus* is tetramerous; while I have seen four Comatulæ with the same peculiarity, and one with six rays. Four and six rays are more common in *Rhizocrinus* (Pl. VIIIa. figs. 6, 7), and in very rare cases there may be seven. In the Comatulid genus *Promachocrinus*, however, ten is the normal number, but the basals are pentamerous. Only five rays extend outwards from the central rosette to appear externally beneath five of the radials (fig. 1, A), and they must therefore be regarded as representing the primary interradii of the type. Hence those radial pieces which are not separated from the centro-dorsal by basal rays are the original embryonic radials, homologous with those of other Crinoids and of the five-rayed Star-fishes. The five others may perhaps be compared to the additional radials developed in many-armed Star-fishes, in which, however, the positions of the five primary rays are not indicated in the adult as they are in *Promachocrinus*.

C. The Interradials.

In almost all adult Neocrinoids the first radials meet one another all round the calyx so as to form a complete ring; and until lately this character has been regarded as one specially distinctive of the group. For in a large number of Palæocrinoids an anal plate retains its primitive embryonic position and rests upon a basal, thus separating two of the radials and destroying the complete pentamerous symmetry of the calyx. A good instance of this type is the Carboniferous genus *Belemnocrinus*, which has a calyx very similar to that of the recent *Rhizocrinus* except for the presence of the intercalated anal

plate. *Hexacrinus, Dichocrinus,* and their allies present a similar condition. In a few genera of the Rhodocrinidæ, which have been grouped together into a section *Rhodocrinites* by Wachsmuth and Springer, the radials are not contiguous laterally; but between every two there is an interradial plate which rests on a basal below.

This character, which occurs in no stalked Neocrinoid, either recent or fossil, reappears in the singular Comatulid *Thaumatocrinus*[1] (Pl. LVI. figs. 1–4). But with this exception all the primary radials of every adult Neocrinoid, recent or fossil, stalked or free, form a complete ring.

Calyx-interradials are very usually present in the Palæocrinoids, helping, together with the higher orders of radials, to increase the size of the cup, and strengthen its walls.

According to Wachsmuth and Springer[2] "The first interradial is always larger than any of the rest, and is situated between the upper sloping margins of the adjoining first radials, except in some species of the Rhodocrinidæ, in which it rests directly upon the basals, separating the ring completely. There are generally two plates in the second series, and two or three in each succeeding one."

In the Mesozoic genus *Guettardicrinus,* and in some species of *Apiocrinus* (*Apiocrinus martini, Apiocrinus roissyanus*), there are calyx-interradials essentially similar to those of the Palæocrinoids. Each series commences with a single plate resting upon the upper angles of two first radials which are truncated for its reception (see fig. 9, on p. 183). It is followed by several others, more or less irregularly arranged; and these, together with the two outer radials, and sometimes also the two lower brachials, form the immovable wall of a large cup just as in the Palæocrinoids. No recent Crinoid presents this condition, at any rate in the adult state; though it occurs in many Ophiurids, as pointed out elsewhere.[3] But in all the Pentacrinidæ, recent and fossil,[4] the interradials, if present, are not calyx-plates at all, but merely small and more or less irregular plates developed in the perisome which unites the rays and their subdivisions (Pl. XIII. fig. 1; Pl. XXXI. fig. 2; Pl. XXXIV. fig. 1; Pl. XXXV. fig. 2; Pl. XXXVII. fig. 1; Pl. L. fig. 1). It would seem, however, that regular calyx-interradials may appear in the early larval stages of *Antedon rosaceа.* At any rate this is the way in which I should interpret the following statement by Sir Wyville Thomson.[5] "In one or two cases, however, I have observed about the time of the first appearance of the anal plate, a series of five minute rounded plates developed interradially between the lower edges of the oral plates and the upper edges of the basals." These plates therefore, separate the radials from one another all round the calyx. Their ultimate fate is uncertain. Sir

[1] On a new Crinoid from the Southern Sea, *Phil. Trans.*, 1883, pp. 919–926, pl. 71.

[2] Revision, part ii. p. 12.

[3] On the Apical System of Ophiurids, *Quart. Journ. Micr. Sci.*, vol. xxiv., N.S., January 1884, p. 12.

[4] See, for example, Quenstedt's Encriniden, Tab. 101, figs. 23, 39A; Austin's Crinoidea, pl. xiii. fig. 1c; and Buckland's Geology (Bridgewater Treatise), vol. ii., pl. liii. fig. 2.

[5] *Phil. Trans.*, 1865, p. 540.

Wyville made no further reference to them except to say that they sometimes remained permanently in the adult *Antedon*, usually in groups of three or five. These last, however, like those already noticed in *Pentacrinus* (Pl. XIII. fig. 1), are merely perisomatic plates developed in the tissue uniting the second radials. Good figures of them were given by Dr. Carpenter;[1] and it is by no means certain that they are a further development of the primitively single plates which appear between the orals and basals, for the direct continuity of the two structures has never been definitely traced.

I am inclined to believe that where they do appear in ordinary Comatulæ these primary calyx-interradials eventually undergo resorption like the orals and the anal plate. But they are permanent in *Thaumatocrinus* (Pl. LVI. figs 1–4), as are also the orals (fig. 5). This remarkable genus has five calyx-interradials which rest on basals and separate the radials just as in certain Ophiurids and in some types of the Palæozoic Rhodocrinidæ. It is much to be regretted that this extraordinarily interesting form is only represented by a single individual. For the study of the distribution of the axial cords within the calyx would have been of some importance.

If *Thaumatocrinus* resembles the ordinary Comatulæ and Pentacrinidæ, the circular commissure (Pl. XXIV. fig. 9, *c.co.*, *i.co.*) is formed by both interradial and intraradial commissures which connect the paired branches of the five primary interradial cords (Pl. XXIV. figs. 7–9; Pl. LVIII. figs. 1–3—*ar*); and the interradial commissures must traverse, or at any rate, lie upon the inner surfaces of the interradial plates. But the general embryonic characters of *Thaumatocrinus* lead me to think that the arrangement of its axial cords must be more like that which occurs in *Bathycrinus*. In this genus the primary cords do not fork within the basal ring, but pass upwards through it and enter more or less complete canals which are formed by the apposition of two grooves, one on each of the contiguous lateral faces of adjacent radials (Pl. VII. fig. 6*a*). When they reach about half the height of the radials they fork, and the resulting branches themselves form the interradial commissures, entering the radials by the apertures in their lateral faces.

I cannot help suspecting that the same condition may occur in *Thaumatocrinus*, *i.e.*, that the primary interradial cords run upwards through the basals into the interradials, and there fork, one branch entering each of the two radials which are separated by the interradial lodging the primary cord. This simple condition would correspond very well with the general embryological characters of the type, as revealed in other ways. But owing to the want of material there is unfortunately but little chance of the above hypothesis being verified or disproved.

While resembling the Rhodocrinites in having five large plates separating the radials, *Thaumatocrinus* differs from most Palæocrinoids, with the exception of the Platycrinidæ, in the absence of any higher series of interradial plates. Except on the anal side these

[1] *Phil. Trans.*, 1866, pl. xxxiii. fig. 7 A, B.

primary interradials of *Thaumatocrinus* all end simply in a free rounded edge at the margin of the disk (Pl. LVI. figs. 1–3, 5), which is doubtless partly due to the simplicity of the arms. For these become free at once, and are not connected laterally by perisome, in which higher orders of radials could be supported. The interradial of the anal side, however, bears a small tapering appendage of four or five gradually decreasing joints, which terminates in a blunt point without any connection whatever with the anal tube near it (Pl. LVI. figs. 2, 4, 5). It appears to me to be of the same nature as the so-called proboscis of *Taxocrinus*, *Gnorimocrinus*, *Onychocrinus*, &c. The anal plates of these genera do not support a huge "ventral sac," such as occurs in the Cyathocrinidæ, but are of an altogether different nature. Good figures of them are given by Schultze,[1] Angelin,[2] and by Meek and Worthen.[3] They may be advantageously compared with figs. 2 and 4 on Pl. LVI.

According to Wachsmuth and Springer[4] the first anal plate of *Taxocrinus* "has a truncated upper side, and is succeeded by from two to six similar, narrow, quadrangular plates, longitudinally arranged. The plates diminish in size upwards, and form the dorsal side of a short and slender lateral proboscis, whose ventral parts, as well as the wall supporting them, have never been found preserved, and evidently consisted of more fragile material." A few pages farther on they describe *Onychocrinus* as follows:—"In the anal area there is a series of from three to five very narrow, quadrangular plates, which rests upon the truncated or slightly excavated upper side of the basal, and forms a small lateral proboscis as in *Taxocrinus*. Interradials three to twenty, perhaps more in some species; the first one large, resting between the first and second radials, the succeeding ones smaller, rapidly decreasing in size and thickness upward, and having an inward curvature. They are followed by very minute irregular polygonal plates, which form the interradial portion of the vault." Meek and Worthen[5] described this anal series as resting upon the larger truncated basal, "much as the arms of *Platycrinus* rest upon the first radials, and really looking very much like a diminutive arm rising from the anal area. This arm-like range of small pieces seems never to consist of more than from four to six or seven pieces, which are so small and narrow as to leave a wide open space between them and the posterior rays on each side." Subsequently, however, they met with a specimen showing "the space between the little arm-like range of anal pieces, and the radials and vault to be occupied by very numerous minute pieces."[6] These last occur in each interradius, and are directly continuous with those forming the so-called "vault" or ventral disk, just in the same way as the perisomic plates between the rays of recent Crinoids (Pl. XIII. fig. 1; Pl. XXXIV. figs. 1, 2; Pl. L. figs. 1, 2), of *Extracrinus*, and

[1] Monographie der Echinodermen des Eifler Kalkes, *Denkschr. d. k. Akad. d. Wiss. Wien.*, Bd. xxvi., 1866, Taf. iv. figs. 2, 2*b*, 3, 4*b*.

[2] Iconographia Crinoideorum, Stockholm, 1878, Tab. xvii. fig. 8; Tab. xx. figs. 9, 13, 16; Tab. xxiii. fig. 5.

[3] Palæontology of Illinois, vol. v. pl. xiv. fig. 4.

[4] Revision, part ii. p. 46. [5] Palæontology of Illinois, vol. ii. p. 243. [6] *Ibid.*, vol. iii. p. 494.

of *Apiocrinus*, are continued upwards on to the surface of the disk between the ambulacra. Wachsmuth and Springer described this ventral disk of *Onychocrinus* and of other Ichthyocrinidæ as "composed of a more or less soft or scaly integument, yielding to motion in the body and arms;"[1] and they regard it as homologous with the more solid vault of *Platycrinus* and *Actinocrinus*. I believe, however, as I shall explain more fully further on, that this was the real ventral surface of the Crinoid and not a "vault" at all; while the so-called proboscis or anal tube with the small interradials round it is just in the condition which the anal appendage of *Thaumatocrinus* would assume, did it exist in a larger Crinoid such as *Pentacrinus asteria* (Pl. XIII. fig. 1), with a well-plated perisome between the rays. This plating may be continued up on to the disk and to the summit of the anal tube (Pl. VI. fig. 4; Pl. XVII. fig. 6; Pl. XXVI. figs. 1, 2; Pl. XXXIV. fig. 2; Pl. XXXIX. fig. 2; Pl. LV.).

It unites the lower arm divisions closely together; and any additional appendage in the anal interradius would naturally be bound in with it, just as the four to seven joints of the anal appendage in *Onychocrinus* are bound in with the numerous minute pieces between the rays. But I see no reason for supposing that such an appendage would form part of the tube up to its opening, and be in any way grooved on its inner side. For it seems to taper away rapidly and to become merged into the general plating of the anal interradius in the flexible vault, or disk as I should call it. The passages quoted above both from Meek and Worthen, and from Wachsmuth and Springer, would admit of this interpretation; and in the first case at any rate, it seems (from the context) to be the one which was intended. But Wachsmuth and Springer also speak of the anus of the Ichthyocrinidæ as "unknown except in *Taxocrinus* and *Onychocrinus*, which have a small lateral tube."[2] This observation refers to the small appendage already mentioned; but it must not be understood to imply (as it well might) that this appendage is hollow and pierced by the rectum.

Some older Crinoids, however, than *Taxocrinus* and *Onychocrinus* seem to have had an anal appendage like that of *Thaumatocrinus*, which was sometimes surrounded by numerous minute interradial pieces, so as to form a support to the anal side of the disk between the rays. I mean the genera *Heterocrinus*, Hall; *Reteocrinus*, Billings; and *Xenocrinus*, Miller, all from the Lower Silurian of America.[3]

According to Wachsmuth and Springer's definition of *Reteocrinus*, the posterior

[1] Revision, part i. p. 31.

[2] Revision, part i. p. 31.

[3] As regards the second of these, I shall speak of it in the sense in which it is used by Wachsmuth and Springer, Wetherby, and others (Revision, part ii. p. 191; *Amer. Journ. Sci. and Arts*, April 1883, p. 256). I should say, however, that S. A. Miller differs from his fellow-workers in America upon this subject, and refers the species grouped under *Reteocrinus* by Wachsmuth and Springer to, at least, three genera (*Amer. Journ. Sci. and Arts*, August 1883, p. 105; and *Journ. Cinc. Soc. Nat. Hist.*, vol. vi., December 1883, pp. 217–230). As, however, all the species referred by them to this genus appear to possess an anal appendage like that of *Thaumatocrinus*, *Onychocrinus*, and *Taxocrinus*, it is obviously more convenient to consider them all as congeneric, as I am also inclined to do for other reasons (see *Phil. Trans.*, 1883, pp. 923–933).

interradial area is wider than the other four "with a conspicuous row of decidedly larger and more prominent pieces along the median part." Billings[1] gave a good figure of this in *Reteocrinus stellaris*, and spoke of it as follows:—"If this series of joints constitute a true arm there must be six arms in this species." Miller, who has examined the original specimen of *Reteocrinus stellaris*, describes it thus—"Azygous interradial area covered by a large number of plates, probably one hundred or more, very unequal in size, the middle row being decidedly larger and more prominent than the others, so as to form a ridge up the middle. The plates in this row, however, do not rapidly diminish in size and fade out in their distinctive character before reaching the top of the vault; on the contrary, they are longer than the primary radials, four of them reach nearly as high as the secondary radials, and while the specimen is not preserved above this, enough is disclosed to the palæontologist to show that this series continued up the face of a proboscis that extended, may be as far, or farther, than the arms and the pinnules."

In default, however, of further evidence I prefer to believe that the middle row of plates in the anal area of *Reteocrinus stellaris* was of the same nature as, though perhaps on a larger scale than, that of *Reteocrinus nealli*, which Miller describes as follows:—"Azygous interradial area covered by fifty or sixty plates, very unequal in size, the middle row being decidedly larger and more prominent than the others, so as to form a ridge up the middle, while the other smaller and less prominent ones are crowded in, irregularly, on each side. The plates in this middle row, however, have no uniformity in size or shape; the first one is large and elongated, the fourth is small and subquadrate; and the row has become almost obsolete at the sixth plate, where all are nearly of the same size and scarcely distinguishable from the minute pieces which cover the flattened vault, and with which they unite." The figures of this type in the Palæontology of Ohio (vol. i. pl. ii. figs. 3*b*, 3*c*) illustrate this description admirably, the original specimens having doubtless been seen by Miller; while the figure of *Reteocrinus subglobosus* on the same plate (fig. 2*c*) shows the incorporation into the body of a pinnule borne by one of the secondary radials. This pinnule is closely surrounded by the minute interradial plates, but may be distinguished from them at its origin just as the anal appendage is. This condition is still better shown in *Reteocrinus richardsoni*, Wetherby, which has two "fixed pinnules" in the anal interradius, one on either side of the median appendage. All three are "soldered" together by the minute irregular plates which pass insensibly upwards into those of the so-called "vault;" and the ordinary pinnules on the lower parts of the arms after the last axillary are united in just the same way.[2] This condition recurs constantly in the Liassic *Extracrinus* and in the recent

[1] Decades of the Geological Survey of Canada, vol. iv. p. 64, pl. ix. fig. 4*a*.

[2] Descriptions of New Crinoids from the Cincinnati Group of the Lower Silurian and the Subcarboniferous of Kentucky, *Journ. Cinc. Soc. Nat. Hist.*, vol. ii. pl. xvi. figs. 1, 1*a*.

Pentacrinidæ and Comatulæ; and I see no reason to believe that the minute interradials of *Reteocrinus* are in any way different from those of the Neocrinoids. But I regard them as perisomic plates continuous with those of the disk above, which was in no sense a "vault" like that of the Actinocrinidæ. Meek's figure of *Reteocrinus nealli*[1] illustrates this point admirably, and after examining disks like those of *Pentacrinus wyville-thomsoni*, *Pentacrinus alternicirrus*, *Pentacrinus naresianus*, and *Pentacrinus mollis*, together with similar disks in numerous Comatulæ (Pl. XVII. fig. 6; Pl. XXVI. figs. 1, 2; Pl. XXX. fig. 2; Pl. XXXIII. fig. 7; Pl. LIV. fig. 10; Pl. LV.), and also (thanks to the kindness of Mr. Wachsmuth) that of *Reteocrinus nealli*, I find it difficult to believe that the so-called vault of *Reteocrinus* was anything but the true oral surface of the animal.

Miller's genus *Xenocrinus*[2] is in this respect essentially similar to *Reteocrinus*. "The azygos area is remarkably large and covered in the central part by a vertical series of plates having about the same size as the regular radial series; and upon each side of the vertical series there is a depressed area covered by small plates having a tubercle in the central part, as in the regular interradial areas. There are seven plates, each having a length about twice as great as its width, in the vertical series, from the basal plate, upon which the series rests to the top of the vault. This vertical series is continued to the top of the proboscis, and contains in its entire length more than fourteen plates. It has such strong resemblance to the radial series, except as to the branching at the secondary radials, that the general appearance of the body is that of a species having six radial series." Miller figures the specimen with fourteen plates in the vertical series, and remarks that we learn from it that "the proboscis extends as high as, and probably beyond the extremity of the arms." He also says that the small plates between the rays and their subdivisions "continue over the margin of the vault, and undoubtedly cover it, and also more or less of the long proboscis." I do not see, however, that this so-called but unknown proboscis is anything more than an anal tube covered by perisomic plates, as in *Extracrinus* and so many other Neocrinoids. I also doubt whether Miller is right in stating that the vertical series is continued to the top of the proboscis, for (to judge from his figures) he does not seem ever to have met with a specimen perfect enough to show the top as it is shown in Meek's figure of *Reteocrinus nealli*.[3] But I think it quite possible that, considering the size of this vertical series, it may have become free at the top of the calyx as the anal appendage of *Thaumatocrinus* does (Pl. LVI. figs. 4, 5), instead of tapering away quickly and ending on the lower part of the anal tube as in *Reteocrinus nealli*.

The ventral sac or proboscis of *Cyathocrinus* is usually much larger and more

[1] Palæontology of Ohio, vol. i. pl. ii. fig. 3c.

[2] Description of some New and Remarkable Crinoids and other Fossils of the Hudson River Group, *Journ. Cinc. Soc. Nat. Hist.*, vol. iv. pp. 72, 73, pl. i. fig. 3; pl. iv. fig. 6.

[3] Palæontology of Ohio, vol. i., pl. ii. fig. 3c.

complex in nature than that of *Reteocrinus* and *Xenocrinus*. But a transition between the two appears to be presented by some forms of *Dendrocrinus*, *Heterocrinus*, and *Iocrinus*. A little specimen figured by Meek, and referred to the aberrant type *Dendrocrinus casei*, shows the anal side very well.[1] Meek's description runs as follows: —"Anal series with the first piece resting directly upon the upper truncated side of the heptagonal posterior subradial (*i.e.*, basal) hexagonal in form, and bearing in direct succession above a series of hexagonal pieces gradually diminishing in size; while alternating with these similar small hexagonal pieces can be seen on each side of the mesial series, for some distance above the body between the free rays, and connecting with those of the ventral part." His figure is a curious one, and does not quite agree with his description; for there seems to be a single large and pentagonal anal plate which separates two radials and rests in the angle formed by the upper edges of two basals (subradials, Meek). Upon this plate rests a series of seven gradually diminishing hexagonal pieces which stand out prominently from the smaller plates at their sides, just like the middle row of plates in the anal area of *Reteocrinus nealli* with which they seem to be comparable. If they supported a ventral sac like that of the typical *Dendrocrinus*, it was relatively much larger than that of *Reteocrinus nealli*, so that the vertical series of plates would end much farther from its summit than in that species.

Thus then in *Onychocrinus*, *Taxocrinus*, *Reteocrinus*, *Xenocrinus*, and even in *Dendrocrinus casei* the anal side shows this regular vertical series of plates which rests on a basal below and gradually diminishes in size. The only essential difference between it and the anal appendage of *Thaumatocrinus* is that it forms part of the body, being bound in with the rays by minute interradial plates which are not present in the simpler *Thaumatocrinus*. But this is often the fate of the lower pinnules in the Neocrinoids; and it would assuredly also be the fate of an anal appendage in a Crinoid with the same calyx-characters as *Thaumatocrinus*, but standing in the same relation to it as an extensively plated and multiradiate *Comatula* does to the naked and ten-armed *Antedon rosacea*.

In the Cyathocrinoid genus *Heterocrinus* there appears to have been an anal appendage like that of *Onychocrinus* and *Reteocrinus*; but it rested on the upper sloping sides of two adjacent radials instead of on a basal.

In this type, as in the Cyathocrinidæ generally, the capacity of the cup is comparatively small, and the visceral cavity within the disk is almost entirely limited to its anal interradius, which is enormously enlarged, and forms the structure known as the "ventral sac." In *Cyathocrinus* itself this is a heavily plated tube, that commences at the upper edge of the "special anal" plate, above which its characteristic porous structure appears at once. But in *Heterocrinus* the ventral sac appears to be less robust, while the anal

[1] Palæontology of Ohio, vol. i. pl. iii. *bis*. fig. 2*c*, p. 29.

series consists of "a single row of plates, longitudinally arranged, the outer side rounded and forming a prominent ridge, which gives the appearance of an arm."[1]

The physiological condition of this type appears to me to be very similar to that of *Reteocrinus nealli*, *i.e.*, the anal interradius is supported by a special row of plates, the lowest of which are more or less incorporated into the calyx, while the upper ones are closely surrounded by perisomic plates.

In *Poteriocrinus* and *Eupachycrinus* this anal appendage is practically reduced to one plate, the so-called third anal plate, or the first plate of the ventral tube; but it rests on the first anal or azygous plate, which is itself supported by a basal. This azygous plate is absent in *Ceriocrinus*, and the first plate of the tube (anal appendage) comes down to rest directly upon a basal.

Another curious modification is presented by *Iocrinus*. The posterior side of the calyx is occupied by a large plate that rests between two basals and is in line with the radials. It has been variously described as a radial and as an azygous piece.[2] On its upper surface is a triangular plate which "supports on its right sloping side the usual number of brachials, and on the left a row of quadrangular plates, vertically arranged, extending to the tips of the arms, and forming the posterior wall of a large ventral tube. In external appearance these plates resemble the brachials and arm plates, only they are somewhat higher and not quite as wide; they are gibbous and form an elevated ridge, which causes this appendage to resemble an arm or a branch of the ray." This median ridge extends to the full length of the ventral sac, and it is bordered, just as is the case in *Reteocrinus nealli*, by a number of more delicate perisomic plates. I have little doubt that it served the same purpose in both cases, supporting the anal interradius, though in no way specially grooved for the reception of the hind gut. It is well figured by Meek in the Palæontology of Ohio, vol. i. pl. i. fig. 9*b*.

[1] Revision, part i. p. 69.

[2] For further information upon this subject, see Wachsmuth and Springer, Revision, part i. pp. 65, 71; and *Amer. Journ. Sci. and Arts*, vol. xxvi. 1883, pp. 370, 376; also P. H. Carpenter, *Quart. Journ. Geol. Soc.*, vol. xxxviii., 1882, pp. 306, 307.

IV.—THE RAYS.

A. The Ray-divisions and Arms.

The arms of a Neocrinoid, viewed in a strictly morphological aspect, must be regarded as commencing with the first joints beyond the primary radials. The same is the case in many Palæocrinoids, of which Schultze says, "Die Arme (brachia) beginnen unveränderlich da, wo eine deutliche Gelenkfacette eines festen Kelchstückes ihren Ursprung anzeigt."[1] In the Platycrinidæ and other Palæocrinoids, and in all Neocrinoids (excepting perhaps *Guettardicrinus*), this articular face is on the first radial. In the five-armed *Eudiocrinus indivisus* the next joints beyond the radials are syzygial, with pinnules on the epizygals,[2] which clearly shows that they must be considered as arm-joints and not as belonging to the calyx, although they undoubtedly represent the so-called second and third radials of a ten-armed Crinoid. The other species of *Eudiocrinus* have these two primitively separate joints not united by syzygy but articulated, just as in *Thaumatocrinus* (Pl. LVI. figs. 1–4). The second one bears a pinnule both in *Thaumatocrinus* and in *Eudiocrinus varians*; but in *Eudiocrinus semperi* and *Eudiocrinus japonicus* the first pinnule is on the fourth joint after the radial. This would correspond to the second brachial of a ten-armed Crinoid, but it is really the fourth brachial in *Eudiocrinus*. Lastly, in Perrier's *Eudiocrinus atlanticus*[3] the first pinnule is on the fifth brachial, which corresponds to the third brachial of an *Antedon*.

The well-known genus *Rhizocrinus* resembles *Eudiocrinus indivisus* in the syzygial union of the first two joints beyond the primary radials (Pl. X. figs. 1, 2, 6–8, 20). They have generally been called the second and third radials; and there is some ground for this in the case of *Rhizocrinus lofotensis*, as they are considerably broader than all the joints which follow them except the first (Pl. IX. figs. 1, 2). But in *Rhizocrinus rawsoni* (Pl. IX. fig. 3; Pl. LIII. fig. 7) they are not much larger than the four following joints, which contribute with them to support the visceral mass (Pl. X. fig. 20); while the first pinnule is on the last of these, *i.e.*, on the sixth joint above the calyx (Pl. IX. fig. 3; Pl. X. fig. 20). Considering the evidence afforded by *Eudiocrinus*, I think, however, that it will be more consistent to describe *Rhizocrinus* as having only one radial; while the first pinnule would then be on the sixth (*Rhizocrinus rawsoni*) or on the eighth brachial (*Rhizocrinus lofotensis*). The terms second and third radials would then be used only in those cases where there are ten or more arms, owing to the third radials and more or fewer of the

[1] *Op. cit.*, p. 5. See also the genus Actinometra, *Trans. Linn. Soc. Lond.* (Zool.), ser. 2, vol. ii. pp. 20–25, 1883; Zittel's Palæontologie, t. i. p. 339; de Loriol, Paléont. Franç. Terr. Jurass., t. xi. p. 15; Wachsmuth, Revision, part ii. pp. 9, 10.

[2] *Eudiocrinus* and *Atelecrinus*, *Journ. Linn. Soc.* (Zool.), vol. xvi. p. 495, 1882.

[3] Sur des *Eudiocrinus* de l'Atlantique et sur la nature de la faune des grandes profondeurs, *Comptes Rendus*, t. xcvi. No. 11, p. 726.

following joints being axillaries. This is in accordance with the nomenclature employed by Zittel, who speaks of the joint in *Cupressocrinus*, which is called "articulare" by Schultze, and "second radial" by Roemer, as a "first brachial;" while he only describes one series of radials in the five-armed *Pisocrinus*.[1] The developmental history of the plates also indicates clearly that the second and following radials are really arm-joints. For they commence as imperfect rings, which soon become filled up with lengthening fasciculated tissue, just as is the case with the stem-joints and later brachials. But the *first* radials, like the basals and orals, commence as expanded cribriform films; while the endogenous additions by which they are subsequently thickened are cribriform like those of the basals, and not fasciculated like those of the two outer radials and the following arm-joints. Messrs. Wachsmuth and Springer[2] have been led by their study of the Palæocrinoids to the same conclusion, *i.e.*, that "the arms fundamentally commence with the second radials;" although they find in practice that for purposes of description "it is more convenient to regard the arms as commencing with the first free plate beyond the calyx." In very many Neocrinoids with ten or more arms this would be the second radial; and in the multiradiate *Metacrinus* (Pl. XXXVIII.; Pl. XLIII. fig. 2; Pl. XLVI.; Pls. XLVIII.–LII.) this is actually a syzygial joint with a pinnule on the epizygal just as in the simpler *Eudiocrinus indivisus*, but an axillary appears a few joints farther on, and the rays begin to divide. In the other Pentacrinidæ, however, in *Bathycrinus*, *Holopus*, and in most Comatulæ, as well as in the fossil *Encrinus* and Apiocrinidæ, the second joints above the primary radials are axillaries, and it is not till the second (or rarely the first) joints beyond these that pinnules appear. In all these types the axillary and the joint immediately below it are of the same width as the primary radials in the calyx. But in *Marsupites* and in many Palæocrinoids (*Platycrinus*, *Cyathocrinus*, &c.) they are very much smaller than the primary radials, just as the homologous joints are in *Hyocrinus* (Pl. VI.).

The primary radials which form the upper part of the calyx are generally distinguished as the *first* radials; while the following joints, as far as the first axillary inclusive, are called the second, third radials, &c., though they are really only arm-joints as is shown by their bearing pinnules in *Metacrinus* (Pl. XII. figs. 6, 8; Pl. XXXVIII.; Pl. XXXIX. fig. 1; Pl. XLIII. fig. 2; Pl. XLV. fig. 1; Pl. XLVI.; Pl. XLVIII. fig. 1; Pl. XLIX. figs. 1, 2; Pl. L. figs. 1, 8, 10, 14, 16; Pl. LI. fig. 1; Pl. LII. fig. 1). Since, too, it is very convenient for descriptive purposes to use different names for the different regions of the arms, I see no reason for altering the names by which these plates are generally known, provided that their real nature is not lost sight of.

The conventional use of the term "radials" for the joints between the calyx and the

[1] Palæontologie, pp. 348, 349.
[2] *Phil. Trans.*, 1865, p. 541, pl. xxvii. figs. 1, 3; *Ibid.*, 1866, pp. 729, 742, pl. xli. fig. 1.
[3] Revision, part ii. p. 10.

first axillary (inclusive) is particularly advisable in the case of the Neocrinoids. For among all the members of this sub-class which have ten or more arms,[1] *Metacrinus* is the only genus besides *Plicatocrinus* in which the second joint beyond the primary radials is not an axillary, a character which has elsewhere been pointed out as distinguishing the Neocrinoids from the Palæocrinoids.[2] In the various types of Comatulæ and in some species of *Pentacrinus* there is a similar constancy in the number of joints which intervene between the successive axillaries of the dividing arms. I have therefore found it convenient[3] to give special names to the joints composing the primary and secondary arms respectively, and to restrict the term "brachials" to the joints composing those portions of the arms which undergo no further division.

The joints of the primary arms may be called "distichals," a term no longer used with the precise meaning which Müller attributed to it;[4] while the joints of the secondary arms (if there be any) may be termed "palmars." These names are of much use in descriptions of Comatulæ; for in this family the number and character of the segments between the successive divisions of the arms exhibit variations which are, to a great extent, constant in different species, and thus give us the means of classifying them into larger or smaller groups.[5]

The Pentacrinidæ, however, exhibit a much greater irregularity in this respect; and they also present more exceptions to the following rule, which holds good in almost all the Neocrinoids. The first two joints beyond every axillary of the dividing rays are united to one another in the same manner, either syzygy or bifascial articulation, as the second and third radials are. Thus, for example, there is a syzygy between the two outer radials of *Encrinus*, and another between the two lowest brachials. In *Apiocrinus* and *Millericrinus* the corresponding joints are respectively united by bifascial articulations.

This rule holds good in all the ten-armed Comatulæ, whether the joints are articulated (*Antedon rosacea*) or united by syzygies (*Actinometra solaris*); and it is equally true in all the many-armed species with the exception of two groups of Actinometræ, together with a few unusually aberrant types. In one group, which is represented by *Actinometra multiradiata*, the two outer radials and also the first two of the three distichals are articulated by ligaments only; but in all the subsequent arm divisions there is a muscular joint between the first two segments after each axillary, and the second one is traversed by a syzygy, whether it be itself an axillary or a free brachial, while the first bears a pinnule. Another variation occurs in *Actinometra typica*, *Actinometra novæ-guineæ*, and their allies. These forms have three distichals in the primary arms, the first two of which are articulated, while the axillary is a syzygy; but the two outer

[1] This passage does not refer to *Promachocrinus*, in which genus there are *ten primary rays*.

[2] On Allagecrinus, &c., *Ann. and Mag. Nat. Hist.*, ser. 5, vol. vii., 1881, p. 296.

[3] Actinometra, *Trans. Linn. Soc. Lond.*, (Zool.), ser. 2, vol. ii. p. 24.

[4] Bau des Pentacrinus, p. 31.

[5] Classification of Comatulæ, *Proc. Zool. Soc. Lond.*, December 1882, pp. 746, 747.

radials are united by syzygy, as are the first two joints beyond the distichal and all subsequent axillaries. Except in these and a few other cases, however, there is a very great uniformity throughout the arm-divisions of the Comatulæ.

In five of the eight recent species of *Pentacrinus* the two outer radials form a syzygy, and in correspondence with this the lowest distichals and brachials are similarly united in pairs (Pl. XII. figs. 18, 21; Pl. XV. figs. 1, 2; Pl. XVI. fig. 1; Pl. XVIII. figs. 1–3, 8, 11; Pl. XIX. figs. 1, 6, 7; Pl. XXI. figs. 1*d*, 2*d*, 5*a*; Pl. XXV.; Pl. XXVI. figs. 4, 5, 8). On the other hand, the ten-armed *Pentacrinus naresianus* has a bifascial articulation between the two outer radials, and also between the two lowest brachials, just as in *Antedon rosacea* (Pl. XXX. figs. 1, 11, 12, 16, 17). But in *Pentacrinus decorus* and *Pentacrinus blakei* the rays divide twice or thrice; and though the two first joints beyond the lowest axillaries resemble the outer radials in being articulated by ligaments, yet there is a muscular joint between the two lower brachials of the ultimate arms, the second of which is usually a syzygy (Pl. XXXI. figs. 1, 2; Pl. XXXII. figs. 16–18; Pl. XXXIV. figs. 3, 6; Pls. XXXV.–XXXVII.).

The syzygial union of two arm-joints is of a somewhat peculiar character. For the hypozygal entirely loses its individuality as a separate segment of the arm, and bears no pinnule as the epizygal and the remaining brachials do (Pl. XII. fig. 9; Pl. XV. fig. 3; Pl. XXX. figs. 1, 19, 20, 23; Pl. XXXa. figs. 10*a*, 10*b*, 12*a*, 12*b*; Pl. XXXII. fig. 4; Pl. L. figs. 6–16). Thus, for example, in very nearly all Comatulæ the original third and fourth joints of the growing arm differ from those which ultimately appear beyond them. For "whilst the majority of these gradually come to possess the true articulations, and to be separated by the intervention of muscles and ligaments, a certain small proportion become more intimately united on a simpler plan, which admits of no motion between them."[1] The double or syzygial joints thus formed resemble the ordinary brachials in bearing but one pinnule, and they are therefore best considered as single joints. In *Antedon rosaeea*, for example, the third and fourth, the ninth and tenth, and the fourteenth and fifteenth joints of the growing arm are respectively united in pairs by syzygy; but the arm is best described as having syzygies in the third, eighth, and twelfth joints. So again in the numerous Comatulæ, such as *Actinometra parvicirra*, which have axillaries on some or all of the primary arms. Counted from the third radial, the distichal axillary is primitively the fourth joint. The first, as is almost invariably the case, bears no pinnule, while the second has a pinnule, but the third not, for it is united to the following (axillary) joint by a syzygy. The first ray-division would therefore be described as consisting of three distichal joints, the second bearing a pinnule, and the third (axillary) a syzygy.

The same arrangement occurs in the genus *Metacrinus*, which is distinguished from *Pentacrinus* and from all other Neocrinoids by having, not three radials only, but

[1] *Phil. Trans.*, 1866, p. 721.

primitively five or eight. Two instances in which *Pentacrinus* varies in the direction of *Metacrinus* have come under my notice. One is in *Pentacrinus müllèri* (Pl. XV. fig. 2). The second and third radials are articulated, but the latter is an axillary with a syzygy, so that there are primitively four radials. In the other case (*Pentacrinus decorus*) there are seven primitive joints in the ray. The first two above the primary radials are united by a bifascial articulation, while the axillary is a syzygy. I have elsewhere described two specimens of *Millericrinus pratti* in which there are four radials, in one case on two out of the five rays (Quart. Journ. Geol. Soc., vol. xxxviii. p. 35, pl. i. fig. 23). Similar variations occur among the Comatulæ. In one *Antedon* that I have examined, one of the rays consists of five joints, the axillary being a syzygy; while in individuals of two other species, the axillary rests directly upon its first radial, the second radial having remained undeveloped. When there are five radials in *Metacrinus*, as in *Metacrinus angulatus*, the third and fourth bear pinnules; but the second does not, for it is united by syzygy to the third, and has lost its individuality as a separate joint (Pl. XII. figs. 5–10; Pl. XXXIX. fig. 1). The radials of *Metacrinus angulatus*, therefore, are practically four in number, the second of which is a syzygy and bears a pinnule like the third.

In *Metacrinus nodosus*, on the other hand, there are primitively eight radials, but besides the syzygy between the second and third, there is another between the sixth and seventh; so that there are really only six joints, all of which except the first and last (axillary) bear pinnules, while the second and fourth have syzygies, and are as much single arm-joints as the third brachial or any other syzygial joint in the arm of *Antedon rosacea* (Pl. L. figs. 1, 6–16; Pl. LI. fig. 1).

In *Encrinus*, *Extracrinus*, and in most recent species of *Pentacrinus*, as also in a few Comatulæ (*Actinometra solaris*, *Actinometra typica*, &c.), the two outer radials and the first two joints beyond them are respectively united by syzygy. On the principle explained above, each pair would therefore be considered as forming a single joint, so that the true third brachial (itself a syzygial pair) would come to be the second. This would involve our describing these forms as having but two radials, the axillary with a syzygy, and syzygies both in the first and in the second brachials. I think, however, that this would be misleading, and make the difference between this type and that of *Antedon rosacea* and *Pentacrinus naresianus* appear much greater than it really is.

The presence of three radials is such an absolutely constant character in all the five-rayed Neocrinoids excepting *Metacrinus* and *Plicatocrinus*,[1] that the fact of the outer ones being united by syzygy and not articulated seems to me to be of minor importance; and I do not assign to it the same morphological value as the syzygial union of the third and fourth primitive brachials, in which the former loses its pinnule. No Crinoid with

[1] Zittel has described a six-rayed example of this genus, in which the first joint above the cup (called by him the first brachial) is axillary as in many Palæocrinoids (*Sitzungsb. d. II. Cl. k. baier. Akad. d. Wiss.*, 1882, Bd. i. p. 105).

three radials ever has a pinnule on the second one; and when this becomes the hypozygal of a syzygy, it does not therefore lose its individuality, as is the case with the hypozygals of the ordinary brachial syzygies. Almost the same may be said respecting the first two brachials. Most Comatulæ, like *Pentacrinus naresianus* (Pl. XXXa. figs. 1, 10*a*, 10*b*, 12*a*, 12*b*), have a syzygy in the third brachial with a bifascial articulation between the two preceding joints, of which only the second bears a pinnule. Hence, when these two are united by syzygy, as in *Actinometra solaris*, *Actinometra typica*, &c., the lowest or hypozygal loses no individuality as an arm-joint. They are, therefore, better described as the first and second brachials, and not as a first brachial which "is a syzygy." This method has the advantage of retaining the third brachial as a syzygial joint as a condition which is common to by far the larger number of Comatulæ. For it is only in a very few species like *Actinometra fimbriata* and *Actinometra multiradiata* that there is a syzygy in the second brachial and a pinnule on the first, as is often the case in *Metacrinus*. This is an entirely different type, and arises from the coalescence of the primitive second and third joints of the growing arm.

Syzygial unions of two primitively separate arm-joints occur with great regularity throughout the arms of the Comatulæ. In the two principal genera *Antedon* and *Actinometra*, there are large groups of species typified by *Antedon eschrichti* and *Actinometra parvicirra* respectively, in which syzygies occur at tolerably regular intervals of three joints. It is rare, however, to find a perfectly regular arm, especially in the latter species, in which the "syzygial interval" may vary from 0 to 10 joints.[1] In other species the interval may be as much as twenty joints or more; while it is occasionally two, as in *Antedon rosacea*, and in rare cases one joint only, as in *Rhizocrinus*. But it is generally possible to find a considerable amount of regularity in the number of joints which form the syzygial interval in any given species, and this is often of some value for systematic purposes.

Among the Pentacrinidæ, however, this is only the case to a very slight extent. The syzygial interval is perhaps most regular in *Pentacrinus naresianus* (Pl. XXVIII.); but it is long as in many tropical Comatulæ, and in other Pentacrinidæ the brachial syzygies are usually "few and far between."

In *Rhizocrinus* and *Hyocrinus*, on the other hand, the syzygial union of the primitive brachials is carried on to a very great extent. In the former genus syzygial and muscular unions alternate with one another continuously from the calyx to the arm-ends (Pl. IX.; Pl. X. fig. 20; Pl. LIII. fig. 7). In *Hyocrinus* (Pl. VI. figs. 1, 2), as was well described by Sir Wyville Thomson,[2] the five arms "consist of long cylindrical joints deeply grooved within, and intersected by syzygial junctions. The first three joints in each arm consist each of two parts separated by a syzygy; the third joint bears at its distal end an articulating facet from which a pinnule springs. The fourth arm-joint is intersected by

[1] Actinometra, *loc. cit.*, p. 49.

[2] *Journ. Linn. Soc. Lond.* (Zool.), vol. xiii. p. 52.

two syzygies, and thus consists of three parts, and so do all the succeeding joints; and each joint gives off a pinnule from its distal end, the pinnules arising from either side of the arm alternately." In this type, therefore, two-thirds of the arm-joints lose their individuality altogether. They bear no pinnules and take no part in the movements of the arms. In *Rhizocrinus* half the brachials are in the same condition; while more than half are devoid of pinnules, as the lowest pinnule-bearing joint is the sixth or sometimes even the eighth primitive brachial (Pl. IX.).

It is worth notice that the modes of arrangement of the arm-joints which are characteristic of *Hyocrinus* and *Rhizocrinus* respectively, are precisely paralleled by the condition of certain species of the Palæozoic *Heterocrinus*. Thus in *Heterocrinus constrictus*, Hall, the pinnules are borne alternately on opposite sides of the arm by every third joint; and I have little doubt, from the figures of the arms which are given both by Hall[1] and by Meek,[2] that each group of three joints is intersected by two syzygies just as in *Hyocrinus* (Pl. VI. fig. 1).

On the other hand, the alternation of syzygies and muscular joints, which is so characteristic of *Rhizocrinus*, also occurs in *Heterocrinus simplex*; and Meek's figures[3] show that the opposed syzygial surfaces were striated as in *Apiocrinus* and *Comatula*, and not plain as in *Pentacrinus* and *Rhizocrinus*.

It has been pointed out already[4] that the supposed syzygies in the arms of *Bathycrinus* (Pl. VII. fig. 2; Pl. VIII. figs. 1, 2; Pl. VIIIa. fig. 1) are really articulations of a peculiar type, though the fossæ and vertical ridge are barely visible in the outer parts of the arms, and would probably have escaped notice altogether, but for the very marked differences from ordinary syzygial surfaces which are presented by the apposed faces of the two outer radials, or of two of the paired lower brachials (Pl. VIIa. figs. 16, 19, 20, 22). Nevertheless, the proximal joint of a pair so united resembles the hypozygal of a syzygy in the non-development of its pinnule; and it might therefore be urged that every pair so united should be properly considered as a single joint, just as in the case of a syzygial pair which only bears a pinnule on the epizygal. It must be remembered, however, that the syzygial union is an immovable one, which is far from being the case with any articulation, whether bifascial or trifascial; and the reasons given above for retaining the individuality of the two outer radials and of the first two joints beyond any axillary, even when they are united by syzygy, apply equally well in the case of *Bathycrinus*. For the hypozygal joints of syzygial pairs are not the only ones which never bear pinnules. The lower joint of every pair forming a bifascial articulation is distinguished in the same way, *e.g.*, the first joints of the various arm-divisions in most Comatulæ, and the first brachials of *Pentacrinus naresianus* (Pl. XXXa. fig. 12*b*). The same is also true in the many-armed Pentacrinidæ, when there are many joints in an arm-division and the axillary is

[1] Twenty-fourth Annual Report on the New York State Museum of Natural History, Albany, 1872, pl. v. figs. 13, 14.
[2] Palæontology of Ohio, vol. i. pl. i. fig. 10. [3] *Ibid.*, pl. i. fig. 7. [4] *Ante*, pp. 8, 9.

united to the preceding joint by a bifascial articulation instead of by syzygy. In fact it is a general rule in all Crinoids that pinnules are only borne by those joints which are united to their successors by paired muscular bundles.

The hypozygal in the brachial syzygies may be fairly considered as losing its individuality. Not only does it bear no pinnule, but it takes no part in the movements of the arm. But when two joints are united by ligamentous bundles on either side of a vertical ridge, they are able to share in the lateral movements of the arm, though not in those of flexion and extension; and it therefore seems unreasonable to consider a pair so united as equivalent to one joint only.

Sir Wyville Thomson was accustomed to regard the stem and its appendages as constituting the "vegetative system" of the Crinoid, as distinguished from the more strictly animal portions, viz., the cup and arms. In describing *Rhizocrinus* for example,[1] he specially alluded to the great "preponderance in bulk of the vegetative over the more specially animal parts of the organism;" and he subsequently pointed out that in *Hyocrinus* and *Bathycrinus*,[2] as in *Rhizocrinus*, there is "a comparatively excessive development of the vegetative system." This was generally the case throughout the Bourgueticrinidæ and Apiocrinidæ, none of which have any very great number of arm-joints, though the "body" may be considerably enlarged with the help of the upper part of the stem. Thus, for example, d'Orbigny[3] describes two twenty-armed species of *Millericrinus*, each reaching a total length of one metre, out of which the calyx and arms together only take up 86 and 94 millimetres respectively, less than one-tenth of the whole; while in one ten-armed species the calyx and arms together only measure 29 out of 920 millimetres.

Among the Palæocrinoids there is considerable variation in the relative development of the stem as compared with the body and arms. The latter are often absent altogether, as in the Blastoids[4] and many Cystids; while they are few in number and poorly developed in *Haplocrinus*, *Pisocrinus*, *Symbathocrinus*, &c. On the other hand, the body and arms, so enormously developed in *Crotalocrinus*, are quite extensive in many Cyathocrinidæ and Actinocrinidæ; but the stem is often large and complicated at the same time, as in *Barycrinus* and *Megistocrinus*.[5]

In the Liassic Extracrinidæ the stem, immensely developed as it may be, still falls considerably short of the body and arms in the complication of its structure. *Extracrinus briareus* has a comparatively short stem; but in *Extracrinus subangularis* it may exceed 50 or even 70 feet,[6] with but few cirri except near the calyx, and those

[1] "Porcupine" Crinoids, *Proc. Roy. Soc. Edin.*, vol. vii. p. 771.

[2] *Journ. Linn. Soc. Lond.* (Zool.), vol. xiii. p. 48.

[3] Hist. Nat. des Crinoïdes, pp. 39, 41, 44.

[4] The so-called "pinnules" of the Blastoids cannot be properly compared to those of the Crinoids, for they do not seem to have contained the genital glands.

[5] Revision of the Palæocrinoidea, vol. i. pp. 14, 15.

[6] Encriniden, pp. 271, 291.

only small ones. The arms, however, reach an enormous development, and Quenstedt calculates the total "Krone" to contain not less than five million pieces.[1]

In the recent Pentacrinidæ the arms are generally well developed in proportion to the stem. This proportion is of course least in young individuals, as shown in Pls. XXXV. and LI., while it is greatest in forms like *Pentacrinus mülleri*, *Pentacrinus maclearanus*, *Pentacrinus wyville-thomsoni*, and *Pentacrinus alternicirrus* (Pls. XIV., XVI., XIX., XXV.). These lead a semi-free existence, owing to the fracture of the stem at a node, as was probably also the case in *Extracrinus briareus* with its large "Krone."

Among the Comatulidæ the vegetative system is reduced to a minimum, as they have no stem in the adult condition. The arms, however, are often very extensively developed, far more so than in any recent Pentacrinidæ. The ultimate arms of a *Pentacrinus* or *Metacrinus* do not often exceed forty in number; and they rarely consist of more than one hundred joints, though twenty or thirty more may intervene between the last axillary and the calyx (Pls. XIV., XVI.; Pl. XVIII. fig. 1; Pl. XIX. fig. 1; Pl. XXV.; Pl. XXVIII. fig. 1; Pl. XXXI. fig. 1; Pl. XXXIV. fig. 1; Pls. XXXVIII., XL., XLII.; Pl. XLIII. fig. 4; Pl. XLIV. fig. 2; Pl. XLV. fig. 1; Pls. XLVI., XLVIII.; Pl. XLIX. fig. 1; Pl. LII. fig. 1). On the other hand, although there are quantities of ten-armed Comatulæ, very many species, especially of *Actinometra*, have from forty to sixty arms; some, like *Actinometra bennetti*, and *Actinometra schlegeli*, eighty or more; and in a few gigantic types like *Actinometra nobilis*[2] there may be over one hundred arms. Further, the number of arm-joints is generally from one hundred and twenty to one hundred and fifty, apart from the syzygies; while in a large *Antedon eschrichti* or *Actinometra bennetti* and in other multiradiate species of the latter genus there may be over two hundred arm-joints. Nearly all of them bear pinnules, which are often very long until quite near the arm ends. But in *Metacrinus* and also in *Pentacrinus*, though to a considerably less extent, the development of pinnules stops short some little way from the extremity of the arm; and its outermost segments bear little stumps of two or three joints only, or may even show no signs of pinnules at all (Pls. XXV., XXVIII., XXXI., XXXIV., XXXVIII., XL., XLII.; Pl. XLIII. fig. 4; Pls. XLIV., XLVI., XLVIII., XLIX., LI., LII.).

The same peculiarity is repeated on a smaller scale in the ambulacral plates of the pinnules. Those of Comatulæ (when present) are continued almost to the end of the pinnule (Pl. LIV. fig. 6). But in the Pentacrinidæ the last few pinnule joints, sometimes even four or six, are totally devoid of any ambulacral plating (Pl. XV. figs. 7–9; Pl. XVI. fig. 2; Pl. XLI. fig. 9; Pl. XLVII. fig. 10; Pl. XLIX. fig. 7; Pl. LII. fig. 5). The same is the case with the extremities of the arms. In fact, both in the persistence of the stalk and of the external basals, and also in the nature of the arms,

[1] Encriniden, p. 292.

[2] The specific formula of this type is—a.3.$\frac{2}{3}$.3.3.$\frac{0}{0}$.

the Pentacrinidæ show very clearly that they are rightly regarded as permanent larval forms of the Comatulæ.

Rhizocrinus and *Bathycrinus*, with their relatively large vegetative system, manifest the same character in another way, viz., the absence of pinnules from the arm-bases; though the ambulacral plating is continued to the end of both arms and pinnules (Pl. VII. figs. 2, 7; Pl. VIII. figs. 1, 3, 5; Pl. VIIIa. fig. 1). There is good reason to believe that the late appearance of the basal pinnules (excepting on the second brachial) is a marked developmental character among the Comatulæ;[1] and in one genus, *Atelecrinus*, the first pinnule is as far out as the twelfth brachial, the lower pinnules not developing at all. In *Rhizocrinus rawsoni* it is on the epizygal of the third syzygial pair, or the sixth primitive joint, and in *Rhizocrinus lofotensis* on the epizygal of the fourth pair (Pl. IX. figs. 1–3); while in *Bathycrinus* it may be as many as eleven joints from the radial axillary, though occasionally only eight or nine (Pl. VIII. figs. 1, 3).

In all the genera of living Crinoids, with one singular exception, the mouth is situated at or near the centre of the disk (Pl. III. fig. 2; Pl. VI. fig. 4; Pl. VII. fig. 3; Pl. XVII. figs. 6, 10; Pl. XXVI. figs. 1, 2; Pl. XXXIV. fig. 2; Pl. XXXIX. fig. 2; Pl. LV. figs. 3–7; Pl. LVI. fig. 6), and the arms are about equally developed on all the five rays. But in the large Comatulid genus *Actinometra* the mouth is excentric or even marginal (Pl. LV. figs. 1, 2; Pl. LVI. figs. 7, 8); and there is frequently a considerable amount of difference in the development of the oral or anterior, and the aboral or posterior arms.

Even when all the arms are provided with food-grooves on the ventral surface as in other Crinoids, those which come off round the mouth are usually longer, sometimes considerably so, than those which spring from the hinder part of the disk; while in other species the anterior and posterior arms are all grooved and all equal in length, but the distribution of their syzygies is quite different.

A great many species of *Actinometra*, however, are characterised by a still more striking difference between the anterior and posterior arms. The former have a wide food-groove of the usual character and a well-developed tentacular apparatus at its sides, while they always appear to end in a "growing point." The posterior arms, on the other hand, have an ungrooved and convex ventral surface, which is without any respiratory tentacles at all (Pl. LVI. fig. 7). They are only about half the length of the grooved anterior arms, and, therefore, taper much more rapidly, while they terminate in an axillary segment which bears two pinnules of the ordinary character. The genital glands which they contain are usually far more developed than those of the anterior arms. Not only are there more fertile pinnules, though the total number of pinnules may not be much more than half that of an anterior arm; but the portions of the glands within these pinnules also attain a greater size than in the oral arms, the basal and median pinnules of the latter being usually less swollen than the corresponding pinnules of a posterior arm.

[1] Preliminary Report on the Comatulæ of the Caribbean Sea, *Bull. Mus. Comp. Zoöl.*, vol. ix., No. 4, pp. 14, 15.

A similar inequality in the development of the genital glands has been noticed by Prof. A. Agassiz as occurring in the Echini.[1]

This frequent difference in length between the anterior and the posterior arms of *Actinometra*, accompanied by the difference in the character of their terminal pinnules, seems to be to some extent dependent upon the condition of the respiratory apparatus occupying their ventral surface. When this is well developed the arm seems to have the power of indefinite growth. For in a great many individuals of various species which have all the arms grooved and tentaculate like those of *Antedon*, there is no very appreciable variation in their length or in the development of their genital glands.

There appears to be no rule of any kind respecting the condition of the arms in any given species of *Actinometra*. In the case of *Actinometra parvicirra*, for example, I have seen individuals with thirty-three arms, all of which were grooved and tentaculate; while in another with thirty-one arms as many as nineteen were grooveless and unprovided with tentacles. All sorts of gradations between these two extremes will be found in any large collection of *Actinometræ*.[2] Half the species of this genus which were dredged by the Challenger have more or fewer ungrooved and less developed arms. They may occasionally be found upon the anterior rays; while in *Actinometra nobilis* and *Actinometra magnifica*,[3] which have one hundred arms or more, several of those on each ray are short and less developed, with neither food-groove nor tentacles on their ventral surface (Pl. LVI. fig. 7).

Even in the normal grooved arms of *Actinometra* the lower pinnules are frequently grooveless and non-tentaculate, just as the hinder arms may be (Pl. LXI. fig. 3). Sometimes only three or four, sometimes as many as forty, are in this condition, being more or less swollen by the development of the genital glands within them; but they do not receive any branches from the brachial ambulacrum, which is itself often but imperfectly developed (see woodcut, fig. 4, p. 113). This ungrooved condition of the lower pinnules may also occur on all the arms of some species of *Antedon;* and it is especially remarkable in types like *Antedon acœla* and *Antedon angusticalyx*,[4] which have a strongly plated ventral perisome. The ambulacral grooves of all the arms and of the later pinnules are well protected by plates (Pl. LIV. figs. 4, 7, 8, 9); but they do not extend on to (about) the first twenty pinnules which contain the large genital glands, though the latter are protected by a very close and regular pavement of anambulacral plates (Pl. LIV. figs. 1–3, 5). In other species, however, which have equally plated pinnules, such as *Antedon incerta*,[5] the ambulacra extend over their ventral surface in the usual way (Pl. LIV. fig. 6).

[1] Revision of the Echini, part iv. pp. 680, 681.

[2] Actinometra, *loc. cit.*, pp. 31–41.

[3] The specific formula of this type is—a.3.2.3.3.$\frac{0}{0}$.

[4] The following are the specific formulæ of these types: *Antedon acœla*,—A.10.$\frac{b}{a}$; *Antedon angusticalyx*,—A.3.$\frac{b}{ab}$.

[5] The specific formula of *Antedon incerta* is—A.10.$\frac{a}{c}$.

B. The Pinnules.

The pinnules are repetitions of the arms on a small scale, and are especially adapted for the protection of the genital glands (Pl. Vc. figs. 7, 8, 10, *t*; Pl. VII. fig. 7; Pl. X. fig. 20).

In no case is a pinnule developed earlier than the second joint above the first radials of the calyx. This condition occurs in the two five-armed genera *Thaumatocrinus* (Pl. LVI. figs. 1, 2) and *Eudiocrinus*. One species of the latter (*Eudiocrinus varians*) has this second brachial free and capable of lateral movement, while in another (*Eudiocrinus indivisus*) it is the epizygal of a syzygy. The corresponding radial joint of *Metacrinus* is of the same character, and there are pinnules on each of the following radials as far as the axillary (Pl. XXXVIII.; Pl. XXXIX. fig. 1; Pl. XLII.; Pl. XLIII. fig. 2; Pl. XLIV.; Pl. XLV. fig. 1; Pl. XLVI.; Pl. XLVIII. fig. 1; Pl. XLIX. fig. 1; Pls. L.–LII. fig. 1). But in the majority of Neocrinoids which have the third radial an axillary, the preceding joint bears no pinnule, while it sometimes contributes to the enlargement of the cup.

Pinnules are always absent from every axillary joint, from the hypozygal of every syzygy (Pl. XXXa. fig. 10*b*; Pl. XXXII. figs. 4, 6, 13, 14; Pl. L. figs. 11, 12), and also from the lower one of every pair of joints which are united by a ligamentous articulation; so that in the great majority of Comatulæ, as in some species of *Pentacrinus*, the first joint after each axillary bears no pinnule. In the former group too the pinnules on the third and the four or five following brachials which form the arm-bases, do not appear till after those of the eighth and following joints, though the pinnule of the second brachial is developed comparatively early; while in *Atelecrinus*, *Rhizocrinus*, and *Bathycrinus* more or fewer of the lowest brachials are permanently devoid of pinnules.

The lowest pinnules of the Comatulæ, and in a less degree those of the Pentacrinidæ also, usually differ somewhat from their successors; and they may present a variety of characters, which are of considerable value in the discrimination of species, owing to the comparative constancy of their occurrence. They are frequently distinguished by the presence of spurs or keels upon their basal joints, as in *Actinometra solaris*; or they may be long, slender, flexible, and flagelliform, as in *Antedon rosacea*; or they may be stiff, straight, and spine-like, as in *Antedon protecta*; or they may have large prismatic basal joints, as in *Metacrinus* (Pl. XXXVIII.; Pl. XXXIX. fig. 1; Pl. XLIII. figs. 2, 4; Pl. XLIV. fig. 2; Pl. XLVI.; Pl. XLIX. figs. 1, 2; Pl. L. figs. 1, 2; Pl. LII. fig. 1); or the dorsal surfaces of their joints may have forward projecting keels, as in *Pentacrinus asterius* (Pl. XIII. figs. 1, 14).

Dr. Carpenter[1] has observed that the first pinnules of the ten-armed *Antedon rosacea*, which habitually arch over the disk and are much longer than their successors, are

[1] On the Structure, Physiology, and Development of Antedon (Comatula) rosaceus, *Proc. Roy. Soc.*, vol. xxiv., 1876, p. 226.

extremely susceptible of irritation. When they are touched in the living animal, the whole circlet of arms is suddenly and simultaneously coiled up over the disk; while irritation of one of the ordinary pinnules is simply followed by the flexion of the arm which bears it.

The structure of these "oral pinnules," which in *Antedon rosacea* and allied species are borne by the second brachials, differs very considerably from that of the pinnules on the other arm-joints. For not only are they sterile, but they have neither tentacular apparatus nor ambulacral groove. Their ventral surface is slightly convex, instead of being concave, as in the ordinary arms and pinnules; while the ciliated ambulacral epithelium, together with the subjacent nerve and radial blood-vessel, are also absent. This appears to be the case with the oral pinnules of almost all Comatulæ; while in some species of *Actinometra* whole arms, with all the pinnules which they bear, are in the same condition.

In the Pentacrinidæ, however, the lowest pinnules of the rays are usually all grooved like their successors, and not devoid of the ambulacra with all their accessory structures, as in the Comatulæ (Pl. XXXIV. fig. 2). In fact the pinnule-ambulacra of *Metacrinus* often start directly from the peristome or from the five primary groove-trunks of the disk, instead of from the particular branches corresponding to the arms which bear the pinnules (Pl. XXXIX. fig. 2; Pl. XLIII. fig. 3; Pl. L. fig. 2).

The fact that the pinnules are only arms in miniature is very well shown by the process of their development at the terminal growing points of the young arms. The first indication of a pinnule is the formation of a fork at the growing point, the two limbs of which are at first almost equal (Pl. XXXV. fig. 1). "One of these rami, however, grows faster than the other, and soon takes a line continuous with that of the axis of the arm, from which the other diverges at an acute angle, so that the former comes to be the proper extension of the arm, while the latter soon takes on the characters of a pinnule. Ere long, however, the growing point of the arm again subdivides; two branches are formed as previously; and whilst one of these becomes a continuation of the arm, the other is soon to be distinguished as a pinnule given off from it on the side opposite to that of the first formed pinnule." [1]

In all the Neocrinoidea, with the exception of *Hyocrinus*, the pinnule borne by any joint is small in comparison with the arm of which that joint is a part. But in this aberrant genus (Pl. VI. figs. 1, 2) the pinnule-bearing joints have rather the appearance of axillaries. For the pinnules are large in proportion to the arms, and are nearly equal in length to the parts of the arms which are beyond the joints where they originate, so that the outer ends of all the pinnules, as well as those of the arms, meet nearly on a level. Hence the pinnules of *Hyocrinus* have some resemblance to the "armlets" or small and undivided but pinnule-bearing arms which come off from the inner faces of the axillaries of *Extracrinus*. But their function as pinnules is shown by the way in which they are

[1] *Phil. Trans.*, 1866, p. 734. See also *Trans. Linn. Soc. Lond.* (Zool.), ser. 2, vol. ii., 1877, p. 40, pl. ii. figs. 4, 6.

enlarged to receive the fertile portions of the genital glands, no part of these appearing in the arms (Pl. Vc. figs. 7, 8, 10, *t*; Pl. VI. fig. 1); while they have no appendages of their own as the armlets have in *Extracrinus*.

The peculiar pinnule arrangement of *Hyocrinus* helps us to understand why there are no pinnules upon the axillaries of multiradiate Crinoids. These may be considered as ordinary pinnule-bearing joints, so modified that the pinnule and the continuation of the arm which bears it are equal in size or nearly so. As mentioned above, this is in fact the mode of formation of the pinnules at the growing points of the arms, as is well shown in a very young individual of *Pentacrinus decorus* (Pl. XXXV. fig. 1). The joint which bears the last formed pinnule is an axillary with two nearly equal distal faces; and the pinnule can only be distinguished from the continuation of the arm by the greater length of its component joints. Furthermore, in the short posterior arms of *Actinometra*, the only ones in which the normal mode of termination has been observed,[1] the last joint is an axillary which bears two pinnules of the ordinary character.

In *Rhizocrinus* (Pl. IX. figs. 4, 5) as in *Hyocrinus* (Pl. VI. figs. 1, 2) the pinnule-bearing joints have very much the appearance of axillaries with unequal distal faces; and a similar inequality is shown by the axillaries of *Extracrinus*, each of which bears an "armlet" on one face and the continuation of the main arm-trunk on the other.

Numerous instances of reparation after injury also indicate the close similarity of arms and pinnules. A very common one, sometimes to be met with in *Antedon rosacea*, is as follows:—The epizygal of the third brachial is broken away, carrying with it all the outer part of the arm, as well as the pinnule which it bears. But it is replaced by an axillary with two distal faces, from each of which an arm eventually grows out, one or other of them perhaps dividing again, as in the specimen of *Pentacrinus decorus* shown on Pl. XXXVI. On the other hand, in an abnormal individual of *Metacrinus angulatus*, the eighth distichal is not an axillary, as is usually the case. But it is somewhat swollen and has a slightly larger pinnule than the preceding joint, so that it resembles an axillary with unequal faces. In the specimen of *Actinometra strota* which is represented on Pl. LV. fig. 2, one of the second brachials of the right posterior ray bears two fully developed pinnules instead of an arm and its own proper pinnule, so that it looks like an axillary. There is no disk-ambulacrum corresponding to this undeveloped arm.

Considering therefore the fundamental identity of arms and pinnules, one would scarcely expect that an axillary joint which gives rise to two arms (often unequal in size) should bear a pinnule as well (see pp. 347, 358).

The pinnule arrangement of *Hyocrinus* is totally unlike that of any other Neocrinoid, although, according to Sir Wyville Thomson,[2] we have something very close to it in some species of the Palæozoic genera *Poteriocrinus* and *Cyathocrinus*. These names were probably employed by Sir Wyville in the wide sense, and not with the restricted meaning

[1] Actinometra, *loc. cit.*, p. 40, pl. ii. fig. 6.

[2] *Journ. Linn. Soc. Lond.* (Zool.), vol. xiii., 1876, p. 52.

which they now possess. There are no true pinnules in *Cyathocrinus* proper, but only repeatedly branching arms, which must therefore have contained the genital glands; and each of the branches borne by one of the lower axillaries may fork again several times, so that they cannot be compared to the long, undivided pinnules of *Hyocrinus* (Pl. VI. figs. 1, 2). In *Poteriocrinus*, on the other hand, the successive arm-joints bear pinnules which are not specially different from those of Neocrinoids; while the mode of branching of the arms resembles that characteristic of *Pentacrinus müllerî*, and more especially of *Extracrinus*, the axillaries being generally limited to the outer arms of the ray, and having unequal distal faces.[1]

It is in the curious genus *Barycrinus*, which was separated from *Cyathocrinus* by Mr. Wachsmuth, that we find the nearest approach to the pinnule-arrangement of *Hyocrinus*. According to Wachsmuth and Springer[2] "all the main arms, instead of bifurcating, give off at regular intervals, alternately on opposite sides, and from the inner margins of the plates, short, rounded, simple armlets, which in most species throw off secondary branches as in *Botryocrinus*, and these armlets here as there, probably performed the office of pinnulæ." *Barycrinus hoveyi*, var *herculeus*, M. and W., is one of the exceptional species in which the armlets are simple and without secondary branches. The excellent figure of it which is given by Meek and Worthen[3] shows these armlets to come off alternately on opposite sides just as in *Hyocrinus*, but from every second joint, instead of from every third (Pl. VI. figs. 1, 2). They have unfortunately never been found in a perfect condition; and we cannot tell therefore whether they reached to the level of the top of the arms proper as in *Hyocrinus*, though Meek and Worthen's description seems to indicate that such is the case.

The difference between these armlets of *Barycrinus herculeus* and those of *Extracrinus* is that the former seem to bear no pinnules as the latter do, and must therefore have contained the genital glands; while they come off alternately from opposite sides of the main arm-trunk, and not from its inner one only as in *Extracrinus*.

We have seen that the pinnule of a Neocrinoid is practically a reduced copy of an arm, but modified by the great development of the fertile portion of the genital gland which it contains, that part of the gland which is confined to the arm being usually sterile and known as the "genital cord" or "rachis" (Pl. Vc. fig. 1; Pl. VIIIa. figs. 4, 5; Pl. LX. fig. 6—*gc.*).

Although it would seem improbable that the pinnules of Palæocrinoids are essentially different in nature from those of the Neocrinoids, Messrs. Wachsmuth and Springer have attempted to show that the small alternating plates covering the brachial ambulacra of *Cyathocrinus* are homologous with the pinnules of the Actinocrinidæ and Platycrinidæ. These are long, comparatively slender, and closely arranged side by side

[1] See p. 277.

[2] Revision, part i. p. 101.

[3] Palæontology of Illinois, vol. v. pl. xiii. fig. 2.

just as on the feathery arms of *Antedon eschrichti* and hosts of other Comatulæ; and they are obviously of the same nature as the pinnules of Neocrinoids generally. "When the arms are closed, the two series of pinnulæ of one arm are laid upon each other so neatly, that the arm-furrow must have been thereby perfectly shut off from the surrounding water. No additional covering has yet been observed in these genera, and it was evidently unnecessary. All this seems to point to the conclusion that the pinnulæ had the same functions, partly at least, as the alternate plates in *Cyathocrinus*, &c., and as both have the same position, and evidently could be opened and closed by the animal, we do not hesitate to consider the latter as the homologue of the former, or in fact as rudimentary pinnulæ."[1]

The first sentence of the above passage concerning the pinnules of *Actinocrinus* and *Platycrinus* would apply equally well to any *Comatula* or *Pentacrinus*, whether the ambulacra be plated or not (Pl. XIII. fig. 13; Pl. XIV.; Pl. XVII. fig. 1; Pl. XXVII. fig. 13; Pl. XXXIII. fig. 3; Pl. XLI. fig. 11; Pl. XLVII. fig. 12; Pl. LIV. fig. 1). As regards the last paragraph, I cannot help thinking that it affords an instance in which analogy has been mistaken for homology.

The overlapping of the pinnules so as to cover in the ambulacra may occur in all recent Crinoids; while the grooves of the pinnules themselves, like those of the arms and disk, are often bordered by two more or less distinct rows of minute movable alternating plates, the "covering plates." These may themselves be supported on "side plates," thus making four rows in all, which are sometimes very fully developed as in *Hyocrinus*, together with many Pentacrinidæ and Comatulæ (Pl. Vc. figs. 9, 10; Pl. VIIIa. fig. 5—*cp*. Pl. XIII. figs. 15, 16; Pl. XVII. fig. 8; Pl. XXVII. figs. 4–6, 11–13; Pl. XXXIII. figs. 1–4; Pl. XLI. figs. 4, 11–13; Pl. XLVII. figs. 10–12; Pl. XLIX. figs. 6, 7; Pl. LI. figs. 11, 12; Pl. LII. figs. 5, 6; Pl. LIV. figs. 4, 6–9). Similar plates occur on the pinnules of Actinocrinidæ and Platycrinidæ, their grooves being "covered by a double series of very minute pieces, though, owing to defective preservation, this covering is rarely observed."[2] These pinnules "fit together so neatly and cover the arm-furrow so perfectly that additional plates were scarcely needed."[3]

A teleological argument of this kind is, however, no proof that the brachial ambulacra are unprovided with plates in *Actinocrinus* and *Platycrinus*, when there is a double series on the pinnules which they bear; and, as a matter of fact, the evidence afforded by the Neocrinoids is all against this view. *Hyocrinus*, *Bathycrinus*, and *Rhizocrinus* all have covering plates on the arms as well as on the pinnules (Pl. Vc. figs. 8–10; Pl. VI. figs. 1–4; Pl. VII. figs. 2, 7, 8; Pl. VIII. figs. 3, 5; Pl. VIIIa. fig. 1; Pl. IX. figs. 1–4; Pl. X. fig. 20). The first of these has side plates on the pinnules (Pl. Vc. figs. 9, 10, *sp.*), but they are not distinctly differentiated on the arms; and the same is the case in the Pentacrinidæ and Comatulæ. But except in *Pentacrinus maclearanus*

[1] Revision, part i. p. 25. [2] *Ibid.*, part ii. p. 25. [3] *Ibid.*, p. 24.

(Pl. XVI. figs. 2, 3; Pl. XVII. fig. 1), with its extraordinarily narrow arm-groove, the ambulacral plating of the pinnule always arises from a similar but less defined skeleton on the brachial ambulacrum (Pl. XVII. figs. 7–9; Pl. XXXIII. figs. 3, 4; Pl. XLI. figs. 4, 13; Pl. LIV. fig. 7). This is itself directly continuous with the ambulacral plates of the disk; while the perisomic plates, which may appear at its sides (Pl. XXVII. figs. 6, 13; Pl. XLI. figs. 4, 13), are in like manner connected with the anambulacral system over the arm-bases (Pl. XXVI. figs. 1, 2; Pl. L. fig. 2). Wachsmuth's own beautiful observations have demonstrated the existence both of anambulacral and of ambulacral covering plates on the upper surface of the body, beneath the vault of *Actinocrinus;* and since the latter also appear on the pinnules, it seems unreasonable to doubt their presence on the arms.

But if, as I firmly believe, brachial covering plates occurred in *Actinocrinus* as in *Cyathocrinus*, what becomes of the supposed homology between these covering plates in the latter genus and the pinnules of the former type?

Mr. Wachsmuth appears to me to have been much nearer the truth when he suggested that the many little branches of the bifurcating arms in *Cyathocrinus* performed the functions of pinnules,[1] though he gave no explanation as to what these functions were. In recent Crinoids, and most probably therefore in the fossil ones also, the functions of the pinnules are threefold, viz., (1) the protection of the fertile portions of the genital glands, which are all connected together by the sterile rachis in the arm; (2) respiration; (3) alimentation.

Dr. Carpenter[2] has pointed out that the Crinoids are very closely dependent for the maintenance of their life upon pure, well aerated water. He alludes to the importance of the pinnated arms in bearing a vast aggregate of tubular tentacles by which respiration is effected; and regards it as probable "that the ordinary pinnules are specially related to the function of *respiration*, in virtue alike of their proper branchial canals, and of the ambulacral canals and the tubular tentacula with which they are furnished."

This process of respiration was doubtless effected just as well by the tentacles connected with the water-vessels in the many-branched arms of *Cyathocrinus*, as by those on the pinnules of *Actinocrinus* or *Comatula;* and there is no reason why the genital glands should not have been contained in these pinnule-less arms, for they frequently extend from the pinnules down into the arms both in *Holopus* (Pl. Vc. figs. 1, 2, *ov.*), in many Comatulæ (Pl. LXI. fig. 3), and even in Pentacrinidæ; so that they often appear in section as taking the place of the sterile genital cord, which unites the more fertile portions of the gland that are contained in the successive pinnules.

The third great function of the pinnules of a Crinoid arm is to present as large an

[1] Notes on the Internal and External Structure of Palæozoic Crinoids, *Amer. Journ. Sci. and Arts*, vol. xiv. p. 120.

[2] *Phil. Trans.*, 1866, pp. 701, 702.

area as possible of the ciliated ambulacral grooves on their ventral surface in order to catch the minute organisms in the surrounding water which might serve as food, and send them down the ambulacra of the arms towards the central mouth. For this purpose, as for that of respiration, the repeated branching of the long arms of *Cyathocrinus* would be as effective as the development of pinnules on the successive joints of less divided arms in other Crinoids. The three great functions of these pinnules would thus have been performed without difficulty by the branching arms of *Cyathocrinus*. But for which of them are the covering plates of the arm-grooves at all adapted, and how far can these plates be considered as repetitions of the arms on a small scale? To each of these questions only a negative answer is possible.

The covering plates of recent Crinoids may be found closed down over the food-groove after death (Pl. XIII. fig. 16; Pl. XVII. fig. 7; Pl. XXVII. fig. 12; Pl. XXXIX. fig. 12; Pl. XLVII. fig. 10; Pl. LI. fig. 12; Pl. LII. fig. 6; Pl. LIV. figs. 4, 6); but they are just as often met with in a more or less erect position, thereby opening the food-groove to the exterior (Pl. Vc. figs. 8–10; Pl. VIIIa. fig. 5—*cp.* Pl. XVII. figs. 2, 8, 9; Pl. XLVII. figs. 4, 13; Pl. LI. fig. 11; Pl. LIV. figs. 7–9). Just in the same way the arms are frequently closed round the disk in the dead animal (Pls. XVIII., XIX., XXV., XXVIII., XXXI., XLV., XLIX., LII.); while in other cases they are more or less expanded, as they were during life (Pls. XXXIV., XL., XLII.). Messrs. Wachsmuth and Springer argue, however, (1) because the arm-groove of the fossil *Cyathocrinus* is closed by covering plates which could be opened and closed by the animal (as it is in the dried arm-fragment of *Pentacrinus asterius* which is shown in Pl. XVII. fig. 7), and (2) because the arm-groove of *Actinocrinus* must have been perfectly shut off from the surrounding water by the apposition of the pinnules *when the arms were closed;* therefore the covering plates of *Cyathocrinus* are homologous with the pinnules of *Actinocrinus.*

But what advantage is it to the animal to have its arm-grooves closed up, whether by covering plates or by pinnules, and so shut off from the surrounding water? It could not breathe properly in this condition, neither could it get its food. None of the food particles which one finds so frequently in the alimentary canal of a Crinoid, *e.g.*, Radiolarians, Foraminifera, Diatoms, &c., could enter the food-grooves of the arms if they were closed by covering plates or by the apposition of the pinnules over them. The habitual expansion of the arms is essential to the whole life of a Crinoid, and Prof. L. Agassiz has well described their movements in the living *Rhizocrinus.* "We had the Crinoid alive for ten or twelve hours. When contracted the pinnules are pressed against the arms, and the arms themselves shut against one another, so that the whole looks like a brush made of a few long coarse twines. When the animal opens, the arms at first separate without bending outside, so that the whole looks like an inverted pentapod; but gradually the tip of the arms bends outward as the arms diverge more and more, and when fully expanded the crown has the appearance of

a lily of the Lilium Martagon type, in which each petal is curved upon itself, the pinnules of the arms spreading laterally more and more as the crown is more fully open. . . . When disturbed, the pinnules of the arms first contract, the arms straighten themselves out, and the whole gradually and slowly closes up."[1]

Taking all these facts into consideration, I cannot but feel that a homology is of no real value when it is based upon the physiological condition of the arm-grooves in the dead animal, and still more in the fossil forms, closed up as they are in every possible way, especially when this condition is one which the living animal only assumes when disturbed, and cannot long maintain without the risk of being both starved and suffocated. The whole point of Wachsmuth and Springer's argument, however, is based upon this closure of the arm-grooves by pinnules and covering plates respectively; and they attempt to support the proposed homology by certain morphological considerations, which must now be discussed.

On each side of the brachial ambulacra of *Cyathocrinus iowensis* there are, according to Wachsmuth,[2] two rows of minute alternating plates, six to each arm-joint. A similar structure is shown in one of Angelin's figures of an arm-fragment of *Gissocrinus punctuosus*,[3] though in another figure only one row of plates is visible at the side of the ambulacrum instead of two, while the explanation of the figures simply says, "Digiti cum pinnulis magnitudine aucta." A somewhat different structure appears in *Cyathocrinus longimanus* figured on the preceding plate.[4] In this species, according to Wachsmuth and Springer,[5] "there are in place of only two, a series of five successive plates from each side, alternately arranged. The plates of each side taper toward the end and enfold over the furrow, covering it as perfectly and in the same manner as in the two former cases (*i.e.*, *Cyathocrinus iowensis* and *Gissocrinus punctuosus*). Angelin gives no description, but in his table of contents he calls the successive plates 'pinnulæ.'" Although, however, Angelin may have used the word "pinnulæ" for these lateral plates, I doubt how far he meant to imply any correspondence with the true pinnules of *Actinocrinus* and *Platycrinus* and other types in which they occur. For in his definition of *Crotalocrinus* he gives the same name to the lateral processes of the arms by which they are united into the well-known complex network; and he then continues, "Perisoma ventrale totum assulis variantibus tectum; assulæ ambulacrales minutæ, biseriatæ ab imis brachiis usque ad extremos digitos radiatim exeunt, quarumque numerus prout digitorum numerus magis magisque per repetitam dichotomiam increscit."[6] The magnificent figure which he gives of the ventral surface of an expanded *Crotalocrinus pulcher*[7] shows that the minute ambulacral plates on the arms are identical with the covering

[1] Quoted by Pourtalès, On a New Species of *Rhizocrinus* from Barbadoes, *Mem. Mus. Comp. Zoöl.*, vol. iv., No. 8, p. 29.

[2] *Amer. Journ. Sci.*, vol. xiv. p. 121.

[3] Iconographia Crinoideorum, Tab. xxvii. fig. 1*f*.

[4] *Ibid.*, Tab. xxvi. figs. 4, 5.

[5] Revision, part i. pp. 24, 25.

[6] Iconographia Crinoideorum, p. 26.

[7] *Ibid.* Tab. viii. fig. 6; see also Tab. xxv. figs. 15, 17.

plates on the arms of *Gissocrinus*, which he described in his generic diagnosis[1] as "pinnulæ brevissimæ verrucæformes." They do not correspond to the "assulæ ambulacrales" of *Gissocrinus*; for these, as pointed out by Wachsmuth and Springer,[2] are the joints of the arm-bases which are recumbent upon the vault, being raised above the general level, and "covered by small alternating plates like the free arms."

Thus, then, the expression "pinnulæ" was used by Angelin for three different types of structure in *Habrocrinus*, *Crotalocrinus*, and *Gissocrinus* respectively. The first of these represent the true pinnules of recent Crinoids; while, as was first recognised by Zittel,[3] the plates on the arms of *Gissocrinus* represent the "Saumplättchen" which Müller had described on the ambulacra of *Pentacrinus*. He takes the same view of the plates which Angelin called "rudimenta pinnularum semiglobosa" in *Cyathocrinus ramosus*. The corresponding plates in *Cyathocrinus longimanus* have indistinct cross markings; and Messrs. Wachsmuth and Springer have interpreted this as indicative of segmentation into pinnule-joints;[4] for they speak positively of "two rows of five successive plates each, one row being given off from the right, the other from the left side of the furrow, and perfectly covering it." The arms of *Cyathocrinus*, however, are only single-jointed; and they state elsewhere[5] that "in double-jointed arms every joint at each side bears a pinnule, while in those with single joints the pinnules are found only on alternate sides." But Angelin's figures show that on five arm-joints there are twelve of these rudimentary pinnules, six on each side, while in *Gissocrinus* there are from four to six on each arm-joint. In spite of these facts, however, Wachsmuth and Springer give it as their opinion that these plates which cover in the ambulacral groove in the arms are the homologues of the pinnules, though too rudimentary to be ranked as such.[6] [See p. 84.]

The chief point of their position (and they make the most of it) is the apparent segmentation of the "rudimentary pinnules" into five joints, as shown in Angelin's figures of *Cyathocrinus longimanus*. It would be very desirable if this could be verified on the actual specimens. The presence of two rows on each side of the ambulacrum in *Cyathocrinus*, *Gissocrinus*, &c., is nothing unusual; for they represent the side plates and covering plates of Neocrinoids, of which there may be from five to seven to one arm-joint. Precisely similar plates occur on the pinnules as well as on the arms; and they also form part of the skeleton round the radiating tubes beneath the vault of *Actinocrinus* "which connect with the ambulacral furrows in the arms."[7] But I think that Wachsmuth and Springer would hesitate before considering the two upper rows of plates in these radiating tubes as "rudimentary pinnulæ."

[1] Iconographia Crinoideorum, p. 10. [2] Revision, part ii. p. 91. [3] Palæontologie, pp. 338, 354.
[4] Revision, part i. pp. 24, 82. [5] *Ibid.*, part ii. p. 24. [6] *Ibid.*, part i. p. 82. [7] *Ibid.*, part ii. p. 28.

V.—THE VISCERAL MASS.

The body-cavity enclosed between the dorsal skeleton and the ventral perisome of a Crinoid consists of two principal parts, which have been conveniently designated by Ludwig[1] as the "intervisceral" and the "circumvisceral" cœlom respectively. In some Comatulæ, such as *Antedon rosacea* and *Actinometra strota*,[2] these two divisions of the cœlom are very distinctly separated; while in other types, such as *Antedon eschrichti*, *Actinometra parvicirra*, and also in the stalked Crinoids, it is difficult to fix a definite boundary between them. In the former case the coiled digestive tube, which is covered in above by the ventral perisome, is protected below by a continuous sheet of connective tissue. This forms a definite membrane enclosing the lower part of the visceral mass or disk, and has been spoken of as the visceral layer of the peritoneum.[3] In *Antedon rosacea*, *Actinometra strota*, and similar forms, this visceral layer is only loosely attached to the parietal layer which lines the interior of the cup formed by the rays and arm-bases. The result is that a comparatively slight amount of violence is sufficient to separate the visceral mass from the calyx and to tear the ambulacra across at the arm-bases. The whole visceral mass, including the digestive tube and plexiform gland, together with the circumoral rings of the blood-vascular, water-vascular, and ambulacral nervous systems, is very apt to be turned out of the calyx, which is then left to swim about on its own account.

The so-called "recent Cystidean," *Hyponome sarsii* of Lovén,[4] is, in fact, nothing more than the much-plated visceral mass of an *Antedon* common at Cape York (Pl. LV. figs. 3, 4); and the same thing may happen to the disks of the equally abundant *Actinometra strota* and *Actinometra jukesi*. Several of these isolated disks were dredged by the Challenger, together with a number of entire individuals and some eviscerated calices; and Sir Wyville Thomson informed me that he had observed them perform slow movements of locomotion over a flat surface; while we know from Dr. Carpenter's experiments that the eviscerated but arm-bearing calyx of *Antedon rosacea* will execute the usual graceful movements of swimming as perfectly as the entire animal had previously done.[5]

The characters of the perisome covering the ventral surface of a Crinoid vary considerably. It may be more or less completely covered by plates (Pl. VI. figs. 1–4; Pl. XVII. figs. 6, 10; Pl. XXVI. figs. 1, 2; Pl. XXX. fig. 2; Pl. XXXIII. fig. 7; Pl. XXXIV. fig. 2; Pl. XXXIX. fig. 2; Pl. XLIII. fig. 3; Pl. L. fig. 2; Pl. LV.;

[1] Beiträge zur Anatomie der Crinoideen, *Zeitschr. f. wiss. Zool.*, Bd. xxviii. pp. 306–308.

[2] The specific formula of *Actinometra strota* is—a. R. 10. $\frac{b}{2} \cdot \frac{a}{a}$.

[3] *Proc. Roy. Soc. Lond.*, vol. xxiv. pp. 213–215.

[4] On Hyponome Sarsii, a recent Cystidean, *Canadian Naturalist*, N. S., vol. iv., 1869, pp. 265–268.

[5] *Proc. Roy. Soc. Lond.*, vol. xxiv. p. 453.

Pl. LVI. fig. 5), or it may be entirely bare to the naked eye, although microscopic examination usually reveals the presence of calcareous spicules at the sides of the ambulacra. Its thickness and consistency vary greatly, more particularly in the arms. In *Thaumatocrinus* (Pl. LVI. figs. 2, 4), *Atelecrinus*, *Promachocrinus*, some species of *Eudiocrinus*, in many of the ten-armed *Antedons* of the temperate and Arctic Seas, and also in those from the greatest depths (1000 to 2900 fathoms), the ventral perisome of the arms is quite thin and delicate, except in the median line, where it is occupied by the ambulacra. These are consequently brought close down upon and between the muscular bundles, which are distinctly visible through the thin layer of perisome that covers them. In *Actinometra*, however (Pl. LV. figs. 1, 2; Pl. LVI. fig. 7), and also in the larger tropical *Antedons*, the ventral perisome of the arms is relatively thick and substantial, and no muscular bundles show through it at the sides of the ambulacra. These pass over the arm-bases on to the disk, where they are usually raised, sometimes considerably so, above the general level of its ventral surface. They converge towards the radial centre, where they unite into a smooth flattened space, the peristome; and somewhere in this space, though not necessarily in its centre, is the opening of the mouth.

In all recent Crinoids, with the single exception of the large Comatulid genus *Actinometra*,[1] the peristome is situated at or near the centre of the disk (Pl. III. fig. 2; Pl. VI. fig. 4; Pl. VII. fig. 3; Pl. XVII. figs. 6, 10; Pl. XXVI. figs. 1, 2; Pl. XXXIV. fig. 2; Pl. XXXIX. fig. 2; Pl. XLIII. fig. 3; Pl. LV.; Pl. LVI. figs. 5, 6). The same was doubtless the case, both in the fossil species of these genera, and also in the allied but extinct genera of Neocrinoids, *e.g.*, *Cotylecrinus*, *Eugeniacrinus*, *Apiocrinus*, *Marsupites*, &c.; while the Blastoids and most, if not all, of the Palæocrinoids present the same character.

In all the Comatulæ which have a central mouth, five primary ambulacra diverge from the peristome and fork more or less frequently according to the number of arms which they have to supply (Pl. LV. figs. 3–7). This may also be the case in the Pentacrinidæ, more especially in those species which have a small number of arms (Pl. XVII. fig. 6; Pl. XXX. fig. 2; Pl. XXXIII. fig 7; Pl. XXXIV. fig. 2; Pl. L. fig. 2). But in the multiradiate species the ambulacra of the disk are often quite irregular in their arrangement (Pl. XVII. fig. 10; Pl. XXVI. figs. 1, 2); and in the case of *Metacrinus* the ambulacra of the large lower pinnules sometimes start directly from the peristome or from one of the large primary groove-trunks, instead of from one of the subdivisions of the latter (Pl. XXXIX. fig. 2; Pl. XLIII. fig. 3; Pl. L. fig. 2).

The brachial ambulacra of the regular Crinoids, which have no very great development of limestone in their ventral perisome, are usually well defined and bounded laterally by elevated folds of the perisome. The edge of each fold is cut out into a series of minute marginal leaflets; while at the base of each of these, and to some extent

[1] See Appendix, Note C.

protected by it, is a group of three tentacles arising from the radial water-vessel. These groups of tentacles alternate on the opposite sides of the ambulacrum along the whole length of the arm, and they accompany its lateral branches on to the pinnules.

In the irregular genus *Actinometra* the mouth is not central or sub-central, but excentric or even marginal. It is sometimes radial in position, as in *Actinometra strota* and *Actinometra jukesi* (Pl. LV. figs. 1, 2),[1] and sometimes interradial, as in *Actinometra magnifica* (Pl. LVI. fig. 7); while the number of ambulacra diverging from the peristome may vary, especially in the multiradiate species, from four to ten or even more. In most cases, however, the large interpalmar area which contains the central or sub-central anal tube is bounded by two large aboral groove-trunks, which form a horse-shoe shaped curve, and give off the ambulacra of the lateral and posterior arms. If the mouth be radial these grooves are often tolerably equal and symmetrically arranged as in *Actinometra strota* and *Actinometra jukesi* (Pl. LV. figs. 1, 2). But in types with an interradial mouth like *Actinometra magnifica* or *Actinometra stelligera* (Pl. LVI. figs. 7, 8),[2] the right or western limb of the curve is much larger than its fellow. [See p. 88.] The latter supplies the arms of the left lateral ray only; while the larger right limb represents the posterior ambulacrum combined with part or the whole of the right lateral ambulacrum as well.

In many forms of *Actinometra* more or fewer of the arms which arise from the posterior and postero-lateral portions of the disk are in the ungrooved and non-tentaculate condition, as has been already described; and the disk ambulacra corresponding to them are less developed than those of the normal grooved arms. In fact they may be altogether absent in some of the large multiradiate species such as *Actinometra magnifica* and *Actinometra nobilis*, both of which are remarkable for the presence of ungrooved arms on each ray. In *Actinometra magnifica* for example, which has an interradial mouth (Pl. LVI. fig. 7), not only are all the seventeen arms of the hinder ray entirely unprovided with food-grooves, but more or fewer of the closely crowded arms on each of the other rays are in the same condition, as they do not receive branches of the dividing groove-trunks which supply their fellows.

Faint lines are sometimes visible, indicating the directions which these grooves should have taken, *i.e.*, the positions of the simple water-vessels which are distributed to the ungrooved arms, but give off no tentacular branches. This is particularly well seen in the case of the posterior ray and parts of the hinder divisions of the two lateral rays of *Actinometra magnifica* (Pl. LVI. fig. 7). The primary groove-trunk, which leaves the right lower corner of the peristome to supply the right and posterior rays, divides into two principal branches before reaching the equator of the disk in which the anal tube is situated.

[1] The specific formula of *Actinometra jukesi* is—a. R. $\frac{db}{2}\left[\frac{a}{a}; \frac{\text{in young}}{\text{individuals}}\right]$.

[2] The specific formula of *Actinometra stelligera* is—a. 2. 2. $\frac{a}{a}$.

One of these supplies most of the arms in the anterior division of the right ray, and the other most of those in its posterior division. But some of the arms in both divisions receive no groove at all; and there is only a faint line on the arm-bases indicating the course of the water-vessel which proceeds to the hindermost arms of this ray, while there is a similar line on the eastern side, indicating the course of the water-vessel supplying the hinder arms of the left ray. [Compare fig. 3 on p. 92.]

The posterior ray, however, has no separate ambulacrum of its own upon the disk; and the right limb of the usual horse-shoe shaped curve is therefore incomplete. At the point where the large and widely open primary groove-trunk forks into the two divisions of the right lateral ambulacrum, a faint line may be seen starting from its inner side. This is all that there is to represent the posterior ambulacrum. It curves backwards round the margin of the disk to its hinder edge, gradually becoming less and less distinct the farther it goes, until its ultimate branches to the arm-bases are only traceable with the greatest difficulty. All the arms of this ray are therefore unprovided with ambulacra, and with most of the structures which are correlated with their presence (Pl. LXI. fig. 3). They have neither blood-vessel nor ventral nerve, and their water-vessels are simple tubes like the integumentary water-vessels of the Molpadidæ.

These variations in the development of the ambulacra on the disk and arms of *Actinometra* have somewhat important morphological bearings, as will be explained in a later chapter. Curious malformations of the disk are occasionally to be met with among the Crinoids. Thus in the disk of *Metacrinus angulatus*, which is represented on Pl. XXXIX., there are two anal tubes of unequal size, between which I found a *Myzostoma* reposing. Three monstrosities of *Comatula* disks have also come under my notice. In one case, an *Antedon*, there are two anal tubes as in *Metacrinus angulatus*, but of more equal size; while in another, *Actinometra stelligera*, there are not only two anal tubes, but also two mouths (Pl. LVI. fig. 8). The true mouth is interradial, and there is a large sub-central anal tube immediately behind it, as in all species of this genus. But there is also a second anal tube occupying the interval between the posterior ambulacrum which curves round the western portion of the disk, and the branches of the lateral ambulacrum on its eastern side. This is very irregular in its character, and expands at one portion of its course into a second peristome in which is a small mouth. Lastly, in a specimen of *Antedon rosacea* from Milford, only four ambulacra reach the central mouth, while the fifth (the left antero-lateral) has a second mouth all to itself (Pl. LVI. fig. 6).

A. The Oral Plates.

The well-known oral plates which are so characteristic a feature in the Pentacrinoid larva of *Antedon* and *Actinometra* are resorbed before maturity is reached. But they persist through life in *Holopus*, *Hyocrinus*, *Rhizocrinus*, and *Thaumatocrinus*, imme-

diately surrounding the peristome and covering it more or less completely (Pl. III. fig. 2; Pl. Vc. fig. 6, *O;* Pl. VI. figs. 3, 4; Pl. X. figs. 7, 20; Pl. LVI. fig. 5). Their rudiments appear in the free-swimming larva simultaneously with those of the basals, which are developed spirally round the right peritoneal tube; while the orals appear in a similar spiral around the left one.

The skeleton is at first limited entirely to these two rings of plates, the edges of which meet around the equator of the growing cup, though they ultimately become separated by the appearance of the radials between them.

At the base of the closed pyramid formed by the oral plates is the upper portion of the larval body, in the centre of which the opening of the mouth is formed. The rest of the space above the circular lip and beneath the oral pyramid is occupied by the tentacular vestibule. This, according to Goette,[1] is derived from the left peritoneal tube, and contains the fifteen first formed tentacles which are borne on the water-vascular ring. At a certain period of development the five valves of this oral pyramid gradually separate so as to open the mouth to the exterior and allow of the protrusion of the tentacles; while the floor of the original tentacular vestibule, with the mouth in its centre, becomes the peristome of the growing Crinoid. Five of the tentacles correspond to the intervals between the oral valves; and a conical projection, the commencement of a ray, appears at the base of each of them. The growing rays are supported by the first radial plates, which appear in the rapidly expanding equatorial portion of the body, *i.e.*, the band of perisome between the upper edges of the basals and the lower edges of the orals. As the rays grow the second radials appear between the bases of the orals, and the equatorial band continues to increase in diameter. But the orals maintain their original position round the mouth, so that they become completely separated from the basals and radials by the equatorial perisome and are relatively carried inwards, while the second radials project somewhat outwards. The diameter of the oral circlet continually decreases in proportion to that of the disk, which enlarges rapidly as new arm-joints are added in succession. The orals are thus left as a circlet of five separate plates protecting the peristome in the centre of the upper surface of the disk; and the ambulacral grooves extend outwards between the bases of the orals, as the growing rays carry the first formed tentacles away from the water-vascular ring.

In all the Pentacrinidæ, and also in the Comatulæ, with the single exception of *Thaumatocrinus* (Pl. LVI. fig. 5), the orals eventually undergo a process of resorption, which commences in the latter case before the young *Comatula* detaches itself from the larval stem, so that no traces of the orals are to be found in the adult. Neither are there any in the adult *Bathycrinus aldrichianus* (Pl. VII. fig. 3), nor even in the young *Bathycrinus gracilis* (Pl. VIIIa. fig. 1); though according to the observations of Danielssen and Koren they would seem to be present in *Bathycrinus carpenteri*, but in a

[1] Vergleichende Entwickelungsgeschichte der Comatula Mediterranea, *Archiv f. mikrosk. Anat.*, Bd. xii. p. 621.

reduced and partially resorbed condition.[1] In *Rhizocrinus*, *Hyocrinus*, *Holopus*, and *Thaumatocrinus* they persist through life, and in each case present a different stage of development.

The orals of *Holopus* retain their embryonic position, and are scarcely separated at all from the first radials, coming into close relation with the inner faces of these plates, while the arms are altogether above and outside them (Pl. III. fig. 2). But in *Hyocrinus* (Pl. Vc. fig. 6, *O*; Pl. VI. figs. 1–4) and also in *Thaumatocrinus* (Pl. LVI. fig. 5), though still relatively large, they are separated from the edges of the radials by a marginal zone of perisome which is paved with closely-set plates, and occupies about one-fifth of the total diameter of the disk.

The orals appear to be unequally developed in the two living species of *Rhizocrinus*. In *Rhizocrinus lofotensis* they would seem either to undergo some amount of resorption, or else to remain in a comparatively undeveloped condition. For they are figured and described by Sars[2] as minute valvule-like plates which occupy the central ends of the triangular interpalmar fields on the disk; so that there is a comparatively large amount of perisome between their bases and the edge of the disk, just as there is in many young Comatulæ after separation from the stem. In *Rhizocrinus rawsoni*, however, they are relatively larger, and their bases approach more closely to the lower brachials, from which they are only separated by a narrow band of perisome (Pl. X. figs. 7, 20).

Under these circumstances, therefore, it is hardly to be expected that the orals should be preserved in the fossil species of *Rhizocrinus;* for as they are only united to the calyx by membrane, they would naturally become separated from it when the soft parts were destroyed. In all the recent Comatulæ, with the exception of the archaic type *Thaumatocrinus* (Pl. LVI. fig. 5), they are resorbed before maturity is reached; and if this was not the case in the fossil species, they probably persisted in somewhat the same form as in *Rhizocrinus*. Even in *Holopus* there is no very close connection between the orals and the tubular cup (Pl. III. figs. 1, 2); and the type is so rare in the fossil state, that specimens with the orals preserved are not likely to be found.

In the Palæocrinoids, however, the orals reached a greater development than in the later Neocrinoids, resembling rather the solid plates of *Holopus* and *Hyocrinus* (Pl. III. fig. 2; Pl. Vc. fig. 6; Pl. VI. figs. 1–5) than the mere films of delicate limestone network which represent them in *Rhizocrinus* and in the Comatulæ. It will, however, be more advantageous to postpone the discussion of the nature and position of the oral plates in the Palæocrinoids until the chapter which deals with the relation of these older forms to the Neocrinoids.

[1] Fra den norske Nordhavs-Expedition, Echinodermer, *Nyt Mag. f. Naturvid.*, Bd. xxiii. p. 9.

[2] Crinoïdes vivants, p. 17, figs. 40, 41, 85, 86, 89-91—*o*.

B. The Perisomatic Skeleton.

This name was given by Sir Wyville Thomson[1] to "the basal and oral plates, the anal plate, the interradial plates, and any other plates or spicula which may be developed in the perisome of the cup or disk." He pointed out that the plates of this system are "essentially variable in number and arrangement; most of the minor structural modifications throughout the group depend upon the multiplication or suppression of plates of this series. Even in the same species they are by no means constant," *e.g.*, *Antedon rosacea*. The nature of the basals and orals has been already discussed; and very little need be said about the anal plate. For although this forms an essential part of the cup of the Pentacrinoid larva of *Comatula*, and is of extreme importance in its palæontological relations, yet it disappears soon after the termination of Pentacrinoid life, undergoing exactly the same process of resorption as the orals have previously done. It is curious, however, that there should be no special anal plate in *Hyocrinus*, which has such large orals (Pl. VI. figs. 1–5), while it is also absent in the adult *Rhizocrinus*, and is perhaps never developed at all; for Sars figures a young individual only 25 mm. long in which the first brachials are comparatively large and form a sort of pyramid, while the second brachials are undeveloped, and he makes no mention whatever of an anal plate.[2] Whereas in *Antedon rosacea* the anal plate appears soon after the second radials (which represent the first brachials of *Rhizocrinus*); and it is relatively quite large by the time that the first brachials are developed, forming a nearly complete circle together with the first radials, between two of which it is intercalated.

The interradial plates are those minute disks or granules which occur in the substance of the perisome uniting the rays and their subdivisions, and are sometimes difficult to distinguish from the lowest joints of the pinnules. They were first detected in *Antedon milleri* by J. S. Miller,[3] who figured them as forming one "intercostal" between every two second radials. This was probably due, as remarked by Dr. Carpenter,[4] to his having only employed a low magnifying power in his examination of them. Müller[5] described them as occurring in *Pentacrinus asteria* (Pl. XIII. fig. 1), and noticed their difference from the plates on the ventral surface of the disk which are pierced by the water-pores (Pl. XVII. figs. 6, 10). They are very abundant in some species of the Comatulidæ and Pentacrinidæ, uniting the rays and their lowest divisions very closely together; while in other types they may be wholly or entirely absent in some individuals, and more or less well developed in others. In fact, the same individual may have them in one or two of

[1] *Phil Trans.*, 1865, pp. 540, 541.

[2] Crinoïdes vivants, p. 27. Tab. iv. fig. 95.

[3] This is the *Comatula fimbriata* of Miller, which occurs in Milford Haven. See his Natural History of the Crinoidea, Bristol, 1821, Frontispiece, fig. 2, G.

[4] *Phil. Trans.*, 1866, p. 716.

[5] Bau des Pentacrinus, *loc. cit.*, p. 49.

the interradial angles but not in the others. They are, however, very well developed in many of the fossil Neocrinoids, *e.g.*, *Marsupites*, *Apiocrinus*, and *Extracrinus*; and they often have a very solid and substantial appearance. Like the anal plate they are most important in their palæontological relations; as is also the single calyx-interradial of *Thaumatocrinus* (Pl. LVI. figs. 1–5), which has been already described (*ante*, pp. 39–41).

The margins of the ambulacra of the disk, arms, and pinnules, and the interpalmar areas of the disk, are rarely, if ever, perfectly free from any traces of calcareous structures. Those of the ambulacra may take the form of simple short spicules which are almost entirely limited to the marginal leaflets; or they may be forked and branching spicules, or rounded cribriform plates of variable size, which are movable and can either be erected or closed down over the grooves. They are well developed in *Hyocrinus*, *Bathycrinus*, and *Rhizocrinus* (Pl. Vc. figs. 8–10, *cp*; Pl. VI. figs. 1, 6; Pl. VII. fig. 7; Pl. VIII. figs. 3, 5; Pl. VIIIa. fig. 1; Pl. IX. fig. 4; Pl. X. fig. 20). In the first named genus they are sometimes separated from the dorsal skeleton by other plates which will be noticed later (Pl. Vc. figs. 9, 10, *sp*); and the same is often the case in the Pentacrinidæ and Comatulidæ (Pl. XXXIII. fig. 1; Pl. XLVII. figs. 11, 13; Pl. XLIX. figs. 6, 7; Pl. LI. figs. 11, 12; Pl. LII. figs. 5, 6; Pl. LIV. figs. 4, 6–9).

These covering plates of the ambulacra of *Pentacrinus* were termed "Saumplättchen" by Müller, to distinguish them from the uncalcified marginal leaflets of the ambulacra or "Saumläppchen," which correspond to them in most Comatulæ;[1] while Sars,[2] doubting the mobility of these parts in *Pentacrinus* and *Comatula*, gave the name "lamelles du sillon" to the large, oval, and movable plates which border the ambulacra of *Rhizocrinus*. All three structures, however, are of essentially the same nature. The covering plates of the stalked Crinoids are abundantly represented in many of the Comatulæ, always, however, resting upon a more or less developed "side plate" as in the Pentacrinidæ; and the fact that they are merely an extensive development of the limestone rods and networks in the perisome bordering the ambulacra is evident when all the intermediate stages are examined. All the Pentacrinidæ have plated ambulacra; but this is by no means the case in the Comatulæ, especially in *Actinometra*; though individual species of *Antedon* have a relatively larger and more substantial ambulacral skeleton than any *Pentacrinus* or *Metacrinus* (compare Pl. XXVII. figs. 4, 11, 12; Pl. XXXIII. fig. 1; Pl. XLVII. figs. 11, 13; Pl. LI. figs. 11, 12; Pl. LII. figs. 5, 6; Pl. LIV. figs. 4, 6–9).

The covering plates which border the ambulacra on the arms and pinnules of *Pentacrinus asteria* were briefly mentioned by Müller.[3] But he described them as resting upon the joints of the skeleton, which is not always the case; and in fact, two pages further on he spoke of the plates which are situated on the perisome at the sides of the arms and pinnules, just as on that of the disk; while he does not seem to have

[1] Ueber den Bau der Echinodermen, *Abhandl. d. Berlin Akad.*, Jahrg. 1853, p. 57 (of separate copy).

[2] Crinoïdes vivants, p. 24.

[3] Bau des Pentacrinus, p. 46.

noticed the great differences of form, size, and regularity of arrangement between the ambulacral plates of the arms and pinnules respectively. But he pointed out that the covering plates of the disk-ambulacra rest upon other plates which he called "side plates," and that both are distinguished from the general anambulacral plating of the disk by the absence of water-pores.[1] It is difficult to individualise these plates when looking at the disk from above, as they are so irregularly arranged (Pl. XVII. fig. 6; Pl. XXXIX. fig. 2; Pl. XLIII. fig. 3; Pl. L. fig. 2); but they are more easily distinguished in a cross section of an ambulacrum (Pl. LIV. fig. 11; Pl. LVII. fig. 3, *sp.*).

Müller further mentioned a series of median subambulacral plates as lying beneath the food-groove and water-vessel, which he believed to rest in a furrow along their upper surface;[2] and he described a series of ambulacral pores between the median row and the side plates, which might be related to the tentacles, and possibly served for the passage of vessels connecting these organs with ampullæ. He had previously figured some plates as underlying the sides of the food-groove, with pores in or between them, which he spoke of as "Oeffnungen des Tentakelcanals in die Tentakeln der Tentakelrinne."[3] But it is difficult to make out whether they are identical with those which he subsequently described and figured as ambulacral pores.[4]

In reality, however, there are no pores of this kind beneath the ambulacra of the disk; and there are no large ampullæ connected with the tentacles as there are with the tube-feet of the Stellerids. But there is often a large amount of calcareous tissue beneath the water-vessels of both disk and arms, which takes the form of more or less regular plates (Pl. LIV. fig. 11; Pl. LVII. fig. 4, *sub*; Pl. LXII.). They have no definite arrangement, however, and are practically only a portion of the general limestone plating beneath the upper surface of the disk. Although therefore, owing to their subambulacral position, they are generally equivalent to the rotulæ of the Urchins, the lancet-plates of the Blastoids, and the radial pieces in the oral ring of Holothurians, I do not think that they quite deserve the morphological importance which was attributed to them by Müller. It is possible that the series of plates which were discovered by Prof. Huxley and described by Billings[5] as forming an elongated arch beneath the subtegminal ambulacra of *Actinocrinus rugosus* may be true subambulacral plates. But from the descriptions of them which are given by Meek and Worthen,[6] and also by Wachsmuth and Springer,[7] I am rather inclined to think that they may be the adambulacral or side plates (Pl. LVII. fig. 3, *sp.*).

Besides going somewhat fully into the nature of the ambulacral skeleton in *Pentacrinus asteria*, Müller drew attention, as his predecessors had done, to the plates on the

[1] Bau der Echinodermen, p. 58.
[2] *Ibid.*, pp. 57, 58, Taf. vi. figs. 7, 9, *d*.
[3] Bau des Pentacrinus, p. 70, Taf. ii. fig. 14.
[4] Bau der Echinodermen, pp. 58, 63, Taf. vi. fig. 7, *e*.
[5] On the Cystideæ of the Lower Silurian Rocks of Canada, Geol. Surv. of Canada, Decade iii. p. 27.
[6] Notes on the Structure and Habits of the Palæozoic Crinoidea, Palæontology of Illinois, vol. v. p. 331.
[7] Revision, pt. ii. p. 28.

interpalmar areas of the ventral perisome. They are continuous over the edge of the disk with the perisomatic plates uniting the rays; and he came to the conclusion that while many of the ventral plates are perforated by water-pores which lead downwards into the body-cavity, these openings are never found in the interradii at the sides of the disk.[1] He termed them "anambulacral" to distinguish them from the "ambulacralen Kelchporen für Füsschen;"[2] and this name has been conveniently extended both to the plates which they pierce, and also to the remaining imperforate plates of the interpalmar areas. Owing to the large size of the oral plates in *Hyocrinus*, which are themselves pierced by water-pores (Pl. Vc. fig. 6, *wp*), the number of these anambulacral plates on the disk is very small. But in a large *Pentacrinus* or *Comatula* they may be very extensively developed, and the pores are occasionally to be found on the sides of the disk between the rays (Pl. XVII. figs. 6, 10; Pl. XXVI. figs. 1, 2; Pl. XXXIII. fig. 7; Pl. XXXIV. fig. 2; Pl. XXXIX. fig. 2. Pl. LVII. figs. 1, 3, 4; Pl. LIX. figs. 2, 4, 6—*wp*; Pl. LXII.).

At the edge of the disk the anambulacral plates of its upper surface pass gradually downwards into the interradials, which are developed in the perisome uniting the rays; so that in some species both of *Comatula* and *Pentacrinus* the visceral mass is everywhere protected by a continuous armour of plates. Many of the fossil Pentacrinidæ and also some species of *Apiocrinus* show signs of the same structure. It is especially well-marked in the Liassic genus *Extracrinus*, which had a very large and thickly plated "ventral sac." In fact the disk of these Crinoids seems to have borne stouter plates than that of many of the Palæozoic Ichthyocrinidæ; and I do not understand how the ventral disk of this family, which is described by Wachsmuth[3] "as composed of a more or less soft or scaly integument, yielding to motion in the body and arms," can be compared to anything else than the oral surface of a recent Crinoid, with which, however, Wachsmuth says that it "cannot in the remotest degree be homologised."[4]

I have not seen any good disk of *Pentacrinus asteria;* but, judging from the condition of its peripheral part in the specimen figured by Müller, I imagine it to have been covered with a continuous pavement of tolerably large plates. This is also the case in *Pentacrinus wyville-thomsoni* (Pl. XVII. fig. 6). The interpalmar areas are covered with a very closely-fitting pavement of polygonal plates, the largest of which may be pierced by four or five water-pores. The anal tube, which is plated almost up to its summit, occupies the greater part of the corresponding interradius; but the anambulacral plates which are between it and the mouth (in the specimen figured) are smaller than elsewhere, and less distinctly defined. In fact they look as if they had fused into two irregularly-shaped plates which abut directly on the peristome. A similar fusion of small plates appears to have taken place on the anal tube of the *Metacrinus nodosus*

[1] Bau des Pentacrinus, p. 49.
[2] Bau der Echinodermen, p. 63.
[3] Revision, pt. i. p. 31.
[4] *Amer. Journ. Sci.*, vol. xiv. p. 190.

represented in Pl. L. fig. 2. It seems at first sight to be perfectly bare, but careful examination proves it to be covered by very closely set small plates with ill defined boundaries.

The ambulacra of *Pentacrinus wyville-thomsoni* form rather prominent ridges, which are composed of four irregular rows of plates. The plates of the two inner rows are somewhat elongated transversely and generally closed down over the grooves, representing the covering plates of the pinnule ambulacra.

A well plated disk also occurs in *Pentacrinus alternicirrus* (Pl. XXVI. figs. 1, 2); but the ambulacra are less heavily plated than in *Pentacrinus wyville-thomsoni*, and are therefore not so readily distinguished from the anambulacral plates. These are sometimes larger than in the Atlantic species, and are pierced by abundant water-pores which are not shown in the figure; but they do not always fit quite closely together, so that gaps of bare perisome are visible here and there. As in *Pentacrinus wyville-thomsoni*, the plates are generally larger in the anal interradius than elsewhere.

A disk of *Pentacrinus naresianus* was drawn for Sir Wyville Thomson by Mr. Black (Pl. XXX. fig. 2); but it seems to have been mislaid or else cut into sections, for it has not come into my hands. So far as can be judged from the figure, the anambulacral plates were small; while the ambulacra appear to be well-defined ridges and to come into close union around a very small peristome, which is thus entirely concealed by the apposition of their large covering plates.

I have not seen a disk either of *Pentacrinus maclearanus* or of *Pentacrinus blakei*; but in *Pentacrinus müller*i and *Pentacrinus decorus* it is far from being as completely plated as in the species already noticed (Pl. XVII. fig. 10; Pl. XXXIV. fig. 2). For the anambulacral plates are generally isolated and not in contact with their fellows. They are small and numerous in *Pentacrinus müller*i; but in *Pentacrinus decorus* they are fewer in number and comparatively large, some of them containing as many as twenty water-pores.[1]

There are about four irregular rows of plates on the ambulacra, the inner ones being elongated, and sometimes standing up rather prominently at the edges of the grooves.

The relation of the food-groove to the arm-joints varies greatly in the different species of *Pentacrinus*, so that mere fragments of the arms can be identified by the characters of their ambulacra, quite apart from any peculiarities of their arm- and pinnule-joints.

The middle line of the upper surface on each joint of the brachial skeleton is occupied by a groove of variable depth and width, to which Müller gave the name "arm-groove" (Pl. XVII. figs. 1, 4, 7, 8, 9). It is bordered on each side by the more or less prominent muscle plates of the successive joints; and the vascular structures which are partially

[1] These are omitted in the figure, and the plates are drawn too close together.

contained in it are continued from one joint to another between the two large muscular bundles that unite them. In *Antedon eschrichti* and in many other Comatulæ, more especially those belonging to the genus *Actinometra*, this arm-groove merely lodges the lowest part of the cœliac canal; while the genital cord, with the water-vascular and blood-vascular trunks and the ambulacral epithelium, are all situated above the arm-groove, and separated from it by a variable amount of intervening perisome, so that little more than half the vertical height of the arm is due to its dorsal skeleton. The lower parts of the arms in *Metacrinus murrayi* present a somewhat similar condition (Pl. XLI. fig. 13).

In other Comatulæ, however, and in *Pentacrinus* a great part, sometimes even the whole, of the soft parts of the arm are lodged within the groove on the upper surface of the skeleton (Pl. XVII. figs. 1, 4; Pl. XXVII. fig. 6); and there is no substantial ventral perisome in the ordinary sense of the word, or it is reduced to a mere film, sometimes thinly plated, which covers up the muscular bundles. In many species, and especially in the small deep-sea Comatulæ, this layer of perisome is excessively thin and transparent, so that the food-groove appears to rest upon and between the muscular bundles. In some of the tropical *Antedons*, however, it bears a continuation of the anambulacral plates of the disk, and this is also the case in *Pentacrinus wyville-thomsoni*, *Pentacrinus alternicirrus*, *Pentacrinus naresianus*, and *Pentacrinus blakei* (Pl. XVII. fig. 4; Pl. XXVII. figs. 6, 13; Pl. XXXIII. fig. 3). The third of these, *Pentacrinus naresianus*, has the greatest development of this plated perisome on the arms (Pl. XXVII. fig. 13). It is continuous from one pinnule socket to the next on the same side, so as to cover in both the muscular bundles and also the upper surface of the intervening arm-joint; and the ambulacra are thus distinctly above and outside the arm-groove. They are bordered by large oval covering plates which overlap alternately from opposite sides, and are continued on to the pinnules (Pl. XXVII. figs. 11, 12). These plates do not rest directly upon the pinnule-joints, but are separated from them by a thin limestone band which is a continuation of the lateral plating of the arm. It does not, however, exhibit any differentiation into side plates, though its edges are cut out into alternate teeth and notches (Pl. XXVII. fig. 11). The latter are occupied by the tentacles, but can be closed, or nearly so, by the covering plates which rest on the intervening teeth.

In the arms of *Pentacrinus blakei* (Pl. XXXIII. fig. 3) the sides of the joints bend inwards towards the middle line more than they do in *Pentacrinus naresianus*, so that the arm-groove is narrower, and the ambulacrum practically coincides with it instead of lying above it. It is bordered by long plates which are really the covering plates fused with the side plates. When they pass on to the pinnules the former become more differentiated, but the latter lose their individuality and become parts of a continuous denticulated band just as in *Pentacrinus naresianus* (Pl. XXXIII. fig. 1).

A somewhat different type of ambulacrum is presented by two other Caribbean species, *Pentacrinus asteria* and *Pentacrinus decorus*. The arm-groove of the former is relatively wide and the proximal parts of the ambulacra are distinctly above it, though they gradually sink down into it as they get farther from the disk; as long as the rays continue to divide their ambulacra and those of their pinnules are covered by an irregular double row of large plates (Pl. XIII. fig. 16; Pl. XVII. fig. 7). After the last bifurcation these plates become smaller and more regularly arranged, so that they take the form of oblong covering plates with rounded ends which stand up at the sides of the groove (Pl. XVII. fig. 8). They do not, however, extend uninterruptedly along each side of the groove, but are arranged in a series of linear groups between the successive pinnules of either side, so that they alternate in position on the two sides of the arms successively. They are largest and best developed at the base of a pinnule, where its ambulacrum comes off from that of the arm, and from this point they diminish gradually in size towards the disk until the base of the next pinnule is reached, when a fresh set appears upon the proximal edge of its ambulacrum.

Thus, then, the covering plates which pass on to the pinnule-ambulacrum from that of the arm are at first limited to its proximal or outer side only. But a second set soon appears on the inner side of the ambulacrum[1] (*i.e.*, that next the arm), and their outer ends gradually become more and more rounded until they present the appearance shown in Pl. XIII. fig. 15. Their bases are all fused into a narrow band of limestone which rests on the pinnule-joint and represents the side plates that are better developed in other species; while the rounded outer portions represent the covering plates proper, which alternate with one another from opposite sides, so as to leave a series of openings through which the tentacles are extended.

The lower portions of the ambulacra of *Pentacrinus decorus* are essentially like those of *Pentacrinus asteria*, except that they sink more deeply into the arm-groove, while the plates covering them are smaller and far less regularly arranged (Pl. XXXIII. fig. 6). But the muscle plates of the successive arm-joints fit less closely together than in most other species of *Pentacrinus*, so that the muscular bundles are long and also visible externally; for they are not covered in by plated perisome as in the allied *Pentacrinus blakei* (Pl. XXXIII. fig. 3). In the middle and outer parts of the arms the ambulacra are generally like those of *Pentacrinus asteria*, though not so open (Pl. XXXIII. fig. 4); for the groups of plates which protect the bases of the pinnule-ambulacra overlap somewhat closely from opposite sides, while their parts are more distinctly differentiated. Farther out on the pinnules the segmentation of the lateral limestone band is sometimes carried so far that the side plates can be distinctly individualised; but there is a good deal of variation in this respect (Pl. XXXVII. figs. 23, 24).

A third type of arm, with a very narrow median groove to which the ambulacrum is

[1] Compare Pl. XVII. fig. 3; Pl. XLVII. fig. 11.

almost entirely limited, is presented by the four species *Pentacrinus mülleri*, *Pentacrinus maclearanus*, *Pentacrinus wyville-thomsoni*, and *Pentacrinus alternicirrus*. The nearest approach to *Pentacrinus asteria* is to be found in *Pentacrinus mülleri* (Pl. XVII. fig. 9), as might be expected for various reasons. The arm-groove is narrower, but the covering plates which rest on its edges pass up on to the pinnules alternately from opposite sides very much as in *Pentacrinus asteria*; though the successive groups do not overlap one another so much as in that type, and there is more differentiation of the side plates upon the pinnules (Pl. XV. figs. 7, 8). In *Pentacrinus wyville-thomsoni* the arm-groove is still narrower, and the ambulacrum almost entirely withdrawn into it (Pl. XVII. fig. 4). The plates bordering it are smaller and more irregular than in *Pentacrinus mülleri*, and more distinctly limited to the pinnule-bearing side of the arm; while the intervals between the joints are larger and covered by small irregular plates as in *Pentacrinus naresianus* and *Pentacrinus blakei*. The plating of the pinnules is limited at first to their outer sides (Pl. XVII. fig. 3); but it eventually appears on the inner sides as well, and becomes differentiated into covering plates resting on a limestone band which is sometimes imperfectly separable into side plates (Pl. XVII. fig. 2).

A further reduction in the width of the arm-groove and in the size of the plates at its edges appears in *Pentacrinus alternicirrus* (Pl. XXVII. fig. 6). The intervals between successive joints which are occupied by the muscular bundles are larger than in *Pentacrinus wyville-thomsoni*, and are more distinctly plated. The rudimentary covering plates are limited to the origins of the pinnule-ambulacra, and a short distance behind them; so that between every two pinnule-ambulacra of one side there is a short space of unprotected arm-groove. As in *Pentacrinus wyville-thomsoni*, the bases of the pinnule-ambulacra are plated on the outer side only, and in their distal portions the lateral band on which the covering plates rest is not divided into side plates (Pl. XXVII. fig. 5).

Lastly, in *Pentacrinus maclearanus* the arm-groove is extraordinarily narrow, and bounded by little else than the broad plate-like upper surfaces of the component joints (Pl. XVII. fig. 1), while the covering plates are almost entirely limited to the pinnules (Pl. XVI. figs. 2, 3). They are relatively small, and the lateral band supporting them, though broad at first, soon narrows away considerably.

The disk of *Metacrinus* presents much the same variations in the extent to which it is plated as that of *Pentacrinus* does. In *Metacrinus nobilis* (Pl. XLIII. fig. 3) there is a tolerably continuous pavement with well defined ambulacral ridges. These are bounded by about four rows of plates, those of the two inner rows being transversely elongated, and alternating with one another. In other types the anambulacral plates are more isolated as in *Pentacrinus decorus*, being more closely set, however, along the sides of the ambulacra, which are covered by longish plates. This is the case in *Metacrinus angulatus* (Pl. XXXIX. fig. 2), *Metacrinus cingulatus*, and *Metacrinus nodosus* (Pl. L. fig. 2). The scattered arrangement of the anambulacral plates is not well represented in the last

mentioned figure; and it is too small to show the very numerous water-pores piercing the plates, some of which have as many as twelve or fifteen openings. They are much less abundant in *Metacrinus cingulatus* and *Metacrinus angulatus* (Pl. XXXIX. fig. 2), while the plates are also smaller.

The disk of *Metacrinus* differs from that of *Pentacrinus* in the greater irregularity of its ambulacra, the branches of which proceeding to the large lower pinnules often come off directly from the primary groove-trunks, or even from the peristome itself. This is especially well shown in *Metacrinus angulatus* and *Metacrinus nobilis* (Pl. XXXIX. fig. 2; Pl. XLIII. fig. 3).

Another point of difference is the relatively larger size of the anal tube in *Metacrinus*, which is well shown in *Metacrinus nodosus* (Pl. L. fig. 2). It may occupy the whole of the interpalmar area in which it lies, and is often considerably inflated, so as to be a somewhat prominent object on the surface of the disk. It is erroneously represented as perfectly bare in the figure of *Metacrinus nodosus*, and this actually seems to be the case at first sight. Closer examination shows, however, that its apparent bareness is really due to the smoothness and very close approximation of the plates which cover it.[1] They are thinner than the corresponding plates in the other interpalmar areas, and form a smooth continuous pavement over the whole of the lower part of the tube, becoming more nodular and irregular towards the top. The whole appearance of the anal tube in this species forcibly recalls Buckland's well known figure of the "abdominal integument" of *Extracrinus briareus*.[2] There are indications of this close pavement on the anal tube of *Metacrinus nobilis* (Pl. XLIII. fig. 3); and it is better shown in a curious specimen of *Metacrinus angulatus* (Pl. XXXIX. fig. 2), which has a smaller supplementary anal tube by the side of the larger one.

The plates of the pinnule-ambulacra in *Metacrinus* are better differentiated on the whole than those of *Pentacrinus*. For in the outer parts of the pinnules, at any rate, the covering plates rest upon a row of distinct side plates (Pl. XLVII. fig. 11; Pl. LI. figs. 11, 12; Pl. LII. figs. 5, 6), and not upon an almost undivided band of limestone as in most species of *Pentacrinus* (Pl. XIII. fig. 15; Pl. XXXVII. fig. 23).

In the lower parts of the rays and arms the anambulacral plating of the disk extends outwards at the sides of the ambulacra, in which the arrangement of plates is confused and indefinite (Pl. XLI. fig. 13). Farther out, however, where the zig-zag course of the ambulacrum (still distinctly above the arm-groove) is more marked, and the ambulacral plates less abundant, the elongated shape of the plates immediately bordering the groove is more distinctly visible (Pl. XLI. fig. 4). In most species their extremities gradually become bifid, as is well shown in *Metacrinus angulatus* and *Metacrinus murrayi* (Pl. XXXIX. fig. 13; Pl. XLI. fig. 14). Both of these, especially the former, have the

[1] See the remarks on the disk of *Pentacrinus wyville-thomsoni*, *ante*, p. 76.

[2] Geology and Mineralogy, vol. i. p. 439; vol. ii. pl. 51. fig. 2.

ambulacra well above the level of the arm-grooves; and there are no other plates on the arm than the covering plates which really belong to the pinnule-bases, while the muscular bundles are freely visible at the sides of the ambulacra. But in other species, such as *Metacrinus nobilis* (Pl. XLI. fig. 11), the food-groove is more concealed within the arm-groove, and the forked covering plates are less abundant at the pinnule-bases.

Farther out on the pinnule, the proximal half of the fork becomes gradually less and less prominent; and it is eventually absorbed into the basal part of the plate, which thus represents a side plate; while the distal half of the fork, becoming larger and better defined, separates itself off as a rounded covering plate (Pl. XLI. fig. 12; Pl. XLVII. fig. 11).

The branches of the ambulacra which pass on to the massive basal joints of the prismatic lower pinnules are usually but little plated, as is the case in *Pentacrinus asteria* (Pl. XIII. fig. 16; Pl. XLI. figs. 4, 12, 13; Pl. XLVII. fig. 13; Pl. LI. fig. 12). But beyond the first two joints the plating reappears; and the four rows of plates become gradually developed from the irregular plates at the sides of the groove, which come to assume a definite form and break up into covering plates and ill defined side plates.

The gradual differentiation of side and covering plates upon the pinnules from the single forked plates at the sides of the brachial ambulacra takes place in this way in most species of *Metacrinus;* but the four rows are never so distinctly separable as in the Comatulæ (Pl. LIV. figs. 4, 6–9).

A slight variation of this process occurs in *Metacrinus costatus* (Pl. XLVII. fig. 13; Pl. XLIX. figs. 6, 7); while *Metacrinus murrayi* and *Metacrinus nodosus* (Pl. XLI. fig. 12; Pl. LI. fig. 12) are the intermediate links between this species and the other types of *Metacrinus*. The bases of the pinnule-ambulacra just beyond the wide lower joints are bordered by a series of rounded plates, which are deeply hollowed in the centre so that their edges stand up rather prominently. The first eight or ten of these are attached to the pinnule-joints on each side by a continuous band of limestone. This gradually becomes absorbed into the raised proximal edges of the rounded plates so as to form the side plates; while the distal halves eventually separate themselves off as the covering plates (Pl. XLVII. fig. 13). The side plates only become properly differentiated in the outer parts of the lower pinnules, and in the later pinnules on the arms (Pl. XLIX. figs. 6, 7); but they retain a more or less prominent backward process, which is the remains of the raised hinder edge of the rounded plates on the proximal parts of the ambulacra.

Although there are no side plates on the arms and pinnule-bases of *Hyocrinus*, yet they are large and well developed on the enlarged portions of the pinnules which contain the genital glands (Pl. Vc. fig. 10, *sp*). The proximal ones, taking the place of numerous small anambulacral plates, are smaller than their successors, which considerably increase the depth of the body-cavity within the pinnule. Distally, the side plates gradually diminish in size and finally disappear altogether, so that the covering plates come to rest directly on the edges of the pinnule-joints (Pl. Vc. figs. 8, 9).

In many of the tropical Comatulæ the pinnule-ambulacra are fully as well or even better plated than those of the Pentacrinidæ. *Antedon acoela* and *Antedon inæqualis*,[1] both from Stations where Pentacrinidæ are abundant, are good instances of this (Pl. LIV. figs. 4, 6–9). The differentiation of side plates and covering plates is more complete; and the plates themselves are not only larger relatively to the pinnule-joints, but also absolutely so. When the covering plates are erected and the groove opened, as shown in *Antedon inæqualis* (Pl. LIV. fig. 8), the tentacles are extended between them. But the tentacles can be completely retracted and the plates closed down so as to convert the grooves into tunnels, as shown in *Antedon acoela* (Pl. LIV. fig. 4).

In the distal edge of each of the side plates is a small rounded notch, so that there is a series of gaps along each side of the ambulacrum, one between every two plates. These lodge the problematical "sacculi" which are so characteristic of the genus *Antedon*.

In those Comatulæ with plated pinnules which have short and rounded genital glands, instead of the long fusiform structures characteristic of *Antedon eschrichti*, *Hyocrinus*, and the Bourgueticrinidæ, there is sometimes a curious modification of the perisomatic skeleton on the genital pinnules. The enlarged part of the pinnule is protected by a very strongly developed anambulacral plating, which is much more regular and closely set than that of the disk and arm-bases, especially in the case of *Antedon acoela* (Pl. LIV. figs. 1–3). Resting upon the four or five middle joints of the short pinnules there is a double row of large plates, which are rectangular at the base but somewhat more irregular in shape at their upper ends. There are generally five or six plates in each row; but those of the two sides have no fixed relative positions, sometimes corresponding exactly, and sometimes alternating as exactly. They have the same protective function and very much the same appearance as the large side plates of *Hyocrinus* (Pl. Vc. figs. 9, 10, *sp*), but differ from them in two ways. In other species of *Antedon*, such as *Antedon angusticalyx* and *Antedon incerta* (Pl. LIV. figs. 5, 6), these protecting plates are smaller and more irregular than in *Antedon acoela*; while in *Antedon incerta* the two rows are separated by the ambulacrum with its well developed side and covering plates. But in *Antedon angusticalyx* and in *Antedon acoela* these swollen lower pinnules receive no branches from the brachial food-groove, just as in many species of *Actinometra*; and the anambulacral plates covering the genital glands consequently meet one another in the medio-ventral line of the pinnule above the gland within. The sacculi, however, which lie at the sides of the ambulacra may extend on to these grooveless pinnules, and occupy small holes between the large protecting plates; while in the outer joints of the pinnules, beyond the glands, the sacculi occupy the median groove on the upper surface of the skeleton, as is well shown in *Antedon angusticalyx* (Pl. LIV. fig. 5).

[1] The specific formula of this type is—$\bar{A}$. 3(1. or 2p.) $\frac{a^b}{ab}$.

It is curious that these protecting anambulacral plates on the genital pinnules of *Antedon acoela* should be so largely developed,[1] while those which cover the interpalmar areas of the disk are comparatively small and irregular in character (Pl. LV. fig. 5).

In many Comatulæ, however, the disk is very closely plated, both in the ambulacral and in the interambulacral areas. The plates of the latter are mostly small, and rarely pierced by more than one water-pore; while the ambulacra are generally marked by an irregular double row of transversely oblong plates, as in *Antedon angusticalyx* (Pl. LV. fig. 6). But these are sometimes barely distinguishable from the anambulacral plates, and the whole set encroach very much upon the peristome, so that it is scarcely visible in the dry state, as shown in *Antedon basicurva*[2] (Pl. LV. fig. 7). This is still more marked in *Antedon acoela* (Pl. LV. fig. 5). Both the ambulacral and the anambulacral plates are palisade-like in form, as the former are in *Pentacrinus decorus* (Pl. XXXIV. fig. 2); and they are very much crowded, so that the course of the food-grooves can only be made out with difficulty even in spirit specimens, while the peristome is frequently entirely invisible.

The disks of the three *Antedon* species just mentioned are very much incised between the ambulacra, so that they are markedly stellate in form. The arrangement of the coiled digestive tube is consequently much less complex than in large disks like those of *Antedon eschrichti* or of *Pentacrinus*, which have the rays united by perisome so as to increase the capacity of the cup; while the interradial spaces are filled up with connective tissue which supports extensions of the digestive tube.

In some species of *Antedon* with an incised disk the anambulacral plates are somewhat squamous, with a tendency to overlap one another. This is the case, for example, on the disks represented on Pl. LV. figs. 3, 4. They probably belong to *Antedon multiradiata*,[3] having been dredged at Cape York in an isolated condition, together with entire individuals of this species. The edges of the interpalmar areas rise rather sharply towards the ambulacra, which are marked by strong ridges with indications of a median groove visible upon their upper surface. The food-groove beneath is really comparatively deep, with its edges plated somewhat regularly and turned in towards one another. This is very marked in the immediate neighbourhood of the peristome, which is thus completely closed.

[1] The position of the plates which protect the genital glands as regards the pinnule-joints, and the very regular appearance which they frequently present, have led me to think that the so-called "rudimentary pinnules" of *Cyathocrinus longimanus*, Angelin, may possibly be of the same character, and not ambulacral side plates more largely developed than usual (see chap. iv. pp. 62–66). A comparison of Angelin's figures of these structures as seen from the side and from above (Tab. xxvi. figs. 4*b*, 4*c*), with the corresponding views of the protecting plates in *Antedon acoela* (Pl. LIV. figs. 2, 3), shows a remarkable similarity in their number and general arrangement. In the recent form, however, these plates are on the pinnules, while those which they appear to resemble in the Palæozoic *Cyathocrinus* are on the arms. But as these bear no pinnules, and must therefore have themselves contained the genital glands, the difference between the two structures is not so great as it would seem to be at first sight.

[2] The specific formula of this type is—A. 10. $\frac{a}{a}$.

[3] The specific formula of this type is—A. R. 3. 3. $\frac{ab}{c}$.

It is concealed in the smaller specimen by the large and prominent anal tube which projects forwards over it. The original of *Hyponome sarsii*, the "recent Cystidean," was the disk of a plated *Antedon*, very probably of this species, *Antedon multiradiata*.

Allusion has already been made to the frequency with which these disks are met with in an isolated condition; and their resemblance to the curious Palæozoic forms *Agelacrinus, Lepidodiscus*, &c., is very striking. I know that Sir Wyville Thomson had a suspicion whether these problematical organisms may not have been the separated disks of some one or other of the numerous Palæocrinoids, as suggested by Lovén and Lütken.[1]

Deep ambulacral grooves with strongly plated sides are also met with on the disk of *Actinometra strota*. This species is very common at Cape York, and its disk, which was also obtained in an isolated condition, may be nearly bare, or plated very completely, as is shown in Pl. LIV. fig. 10, and Pl. LV. fig. 2. The whole of the large interpalmar area in which the anal tube is situated is covered with more or less scaly plates, which become stouter and more granular in the neighbourhood of the subcentral anal tube. The sides of the deep ambulacra are bounded by numerous smaller plates without any definite arrangement. But they are strictly limited to the disk, not extending on to the arms. The large size of this armature, relatively to the tentacles and the ambulacral groove proper, is well shown in the cross-section represented in Pl. LIV. fig. 11. Much of it extends beneath the water-vessels, and corresponds to what Müller called the subambulacral plates of *Pentacrinus*[2] (Pl. LXII.).

Actinometra jukesi is another species which is common at Cape York. The large anal area is often beset with numerous irregular plates, many of which bear nodules of variable size (Pl. LV. fig. 1). They are smaller on the base and sides of the anal tube; and there are few or none in the small interpalmar spaces between the edge of the disk and the circumferential ambulacra, which are themselves devoid of supporting plates, though deep like those of *Actinometra strota*.

Some species, both of *Antedon* and *Actinometra*, have the ventral perisome of disk and arms entirely devoid of any continuous plating; though this may be strongly developed between the lower divisons of the rays, sometimes extending up to the level of the third axillary.

C. The Visceral Skeleton.

I use the term "visceral skeleton" to denote the numerous spicules and networks of limestone which occur more or less plentifully in the bands of connective tissue that traverse the visceral mass of the Comatulæ. It also includes the more or less regular plates, often quite well defined, which occur *within* the disk of *Pentacrinus*. They are

[1] *Canad. Nat.*, 1869, p. 268.

[2] Bau der Echinodermen, pp. 57, 58, Taf. vi. figs. 7, 9, *d*.

formed, like the anambulacral plates, of a calcareous network interpenetrated by an organic basis, which is of the same nature as in the joints of the rays and arms (Pls. LVII., LXII.).

The simple spicules and thin networks of limestone which occur in the less heavily plated disks are especially abundant in the visceral layer of the peritoneum. This is well seen in those Crinoids, such as *Antedon rosacea*[1] and *Actinometra strota*, in which there is but little connection between this visceral layer and the parietal one lining the interior of the cup, so that the entire visceral mass is readily detached from the calyx.

Unlike that which lines the cup, the oral perisome is usually very closely adherent to the visceral mass, and cannot be separated from it without some trouble. The peritoneal covering of the latter also contains limestone deposits, so that sections through the upper part of the disk show two layers of plates and spicules. The upper one is in the perisome itself, and belongs to the anambulacral system; while the lower belongs to the upper surface of the visceral mass. These lower plates were described and figured by Müller.[2] Together with those of the sides and lower parts of the visceral mass they seem to be the modern representatives of the so-called "intervisceral plexus" which lined the cup of the Actinocrinidæ. Wachsmuth[3] has pointed out that in some members of this family "almost the entire test is lined with a delicate calcareous plexus or network. This lining is not in contact with the test directly, but connected with it by small partitions, producing innumerable little chambers, which communicate with each other and with the visceral cavity." It rarely extends below the level of the second radials, and passes gradually upwards into the plates, coating the interpalmar areas on the upper surface of the disk below the vault. These, which extend right up to the edge of the peristome, are of course anambulacral in character, and it is not easy, any more than it is in *Pentacrinus*, to say where the one set begins and the other ends. But so far as the lower part of the cup is concerned, the intervisceral plexus of the Actinocrinidæ is merely a greater development of the limestone deposits in the visceral layer of the peritoneum of recent Crinoids.

All of these have more or less abundant plates and spicules in the connective tissue which lies beneath the peristome and supports the lip, and also in that which unites the coils of the digestive tube (Pl. LXII.). In the regular endocyclic Crinoids this organ makes rather more than a single round turn upon itself (fig. 2 on p. 89); and it is the aggregation of limestone deposits upon its central side which forms the so-called "columella," once regarded as a sand canal.

This supporting skeleton of the digestive tube, like that enclosing the visceral mass, was much better developed in the Actinocrinidæ than in recent forms. Occupying

[1] Ludwig (*op. cit.*, p. 330, Taf. xix.) has given an excellent diagrammatic section of this type, in which this point is well illustrated.

[2] Bau der Echinodermen, p. 58, Taf. vi. fig. 9, *f*.

[3] Revision, part ii. p. 26.

the greater part of the interior of the cup, but not reaching down to the basals, is a large convoluted organ, which has a general resemblance to the shell of a *Bulla*. It is open at both ends, and its longer axis nearly coincides with that of the body of the Crinoid. Wachsmuth and Springer[1] describe its wall as being "simple in all cases, very delicate, and constructed of an extremely fine filigree work, which generally in the fossil became thickly incrusted with siliceous matter on both sides." Hall, who was the first to notice this organ, made no suggestions respecting its nature. Meek and Worthen supposed it to be a kind of framework supporting the coiled digestive tube;[2] while Wachsmuth and Springer suggest that it might be "an extensive plexus of blood-vessels surrounding the ambulacral (*!*) canal;" and desiring that it "should receive a more appropriate name than any yet given," they propose to call it the "œsophageal network."[3]

That it supported some of the intervisceral blood-vessels I have very little doubt; but there is no reason to suppose that it actually represents the vessels themselves, which would have passed through the meshes of its network (compare Pl. LVII. fig. 5). As a similar though less developed structure occurs in recent Crinoids, I see no reason to doubt the correctness of Meek and Worthen's determination.

Neither do I think Wachsmuth and Springer's name a good one, for it implies that the structure in question was connected with the œsophagus, and not with the rest of the digestive tube. But as it is so large, relatively to the interior of the calyx, the remainder of the digestive apparatus must in that case have been quite small, which is improbable for many reasons.

According to Meek and Worthen,[4] "its slightly dilated upper end seems to stand with its middle almost, but apparently not exactly, under the middle of the nearly central proboscis of the vault; while at the anterior side of its upper margin, and a little out from under the proboscis, it shows remains of a kind of thickened collar, which we found to be composed of minute calcareous pieces. From this there radiate five ambulacra, composed of the same kind of minute pieces as the collar itself."

The thick collar was the edge of the peristome with its more or less regular supporting plates as in any recent Crinoid. The mouth was placed within this peristomial space, and the greater part of the convoluted organ would thus have lain altogether behind it. The direction of its spiral is exactly the same as that of the digestive tube in *Antedon* or *Pentacrinus*, as may be seen by comparing Dr. Carpenter's figure of the latter[5] (viewed from above) and the "inferior end view" of the convoluted organ given by Meek and Worthen.[6] I believe that the gullet ran downwards and backwards as it does in *Pentacrinus;* and that the intestine, after following the convolutions of its support, turned upwards again to end in the long anal tube, the so-called "proboscis."

[1] Revision, part ii. p. 35.
[2] Palæontology of Illinois, vol. v. p. 329.
[3] Revision, part ii. p. 35.
[4] Palæontology of Illinois, vol. v. p. 331.
[5] *Proc. Roy. Soc. Lond.*, vol. xxiv. pl. viii. fig. 1.
[6] Palæontology of Illinois, vol. v. pl. ix. fig. 12*b*.

VI.—THE MINUTE ANATOMY OF THE DISK AND ARMS.

I do not propose to treat the subject of this chapter as fully as I have done the comparative morphology of the Crinoid skeleton. Much has been written about it lately, and a general resumé of this recent work, together with some independent observations of my own, was published in the Quart. Journ. Micr. Sci. for April 1881.

Since that time I have been able largely to increase the range of my observations on the anatomy of the Comatulæ, and have also extended them to *Pentacrinus*, *Bathycrinus*, and *Rhizocrinus*. The result has been that I am able to confirm in almost every respect the admirable investigations of Ludwig on the minute anatomy of *Antedon rosacea*.[1]

On the other hand, there are some points, notably in the relations of the axial cords of the skeleton, which were entirely overlooked by him; while he also omitted to describe some remarkable peculiarities in the structure of the plexus of blood-vessels which is situated in the lip, and is connected with the oral blood-vascular ring.

It is only fair to state, however, that my new observations upon the nervous and vascular systems of this type owe their origin, in great measure, to my having been able to examine other species in which the peculiarities in question are much more developed than they are in *Antedon rosacea*.

A. The Geography of the Disk.

I find that it is most convenient, on the whole, to use the terms *right* and *left* precisely as in human anatomy. When the ventral surface is upwards, with the mouth north, or pointing away from the observer, and the anus posterior, the right side of the disk would be west in a map, and the left side east (figs. 2, 3). On the other hand, when the dorsal surface of the skeleton is upwards, the anal area being, of course, posterior, the eastern rays are those of the right side, and the left rays are in the west. The same method applies to the arms, a pinnule on the right side being east in a dorsal view, and west in a ventral one.

B. The Digestive Tube.

Little need be said about the alimentary canal, the general course of which alters but slightly in the endocyclic Crinoids (*Antedon*, *Pentacrinus*, *Rhizocrinus*, &c.), though it varies a good deal in the complexity of its cavity. Both in *Antedon rosacea* and in *Antedon eschrichti* the gullet runs downwards and backwards, trending slightly to the

[1] *Op. cit.*, *Zeitschr. f. wiss. Zool.* 1877, Bd. xxviii. pp. 255-353, Taf. xii.-xix.

left. When it has reached the bottom of the visceral mass the intestine turns off to the right, and coils round its anterior side. It follows the watch-hand, until it has reached the hinder part of the disk, behind the commencement of the first coil (fig. 2). Here it turns upwards and slightly forwards, to end in the anal tube. The spiral form of the whole organ is thus almost identical with that of the so-called digestive organ in the Palæocrinoids, which I believe to be nothing but the more or less calcified connective tissue that supported the intestinal wall, as explained in the previous chapter.

In simple forms, like *Rhizocrinus* and *Bathycrinus*, more especially the former, the development of the gut is but slightly more advanced than it is in the Pentacrinoid. Horizontal sections through the lowest part of the cup of the larva are remarkably similar to corresponding sections of *Rhizocrinus* and *Bathycrinus*, such as are represented in Pl. VIIb. figs. 6, 7, and Pl. VIIIa. fig. 8.

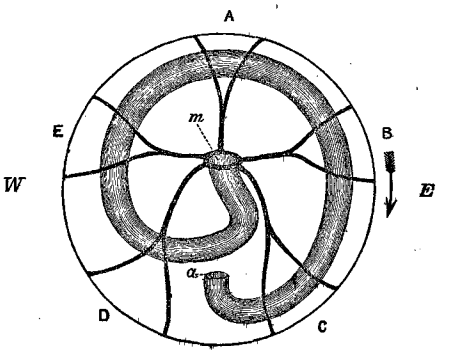


FIG. 2.—Diagram showing the course of the Digestive Tube in an endocyclic Crinoid (*Antedon, Pentacrinus*, &c.), as seen from the ventral side.

A, B, C, D, E, the five ambulacra of the disk; *m*, mouth; *a*, anus.

The lower part of the cup between the second radials is occupied in *Bathycrinus* and in the Pentacrinoid larva by a large expansion of the lowest portion of the coiled gut, just as described in *Rhizocrinus* by Ludwig.[1] It is somewhat kidney-shaped in section, and the concavity is occupied by the plexiform gland, which is always interradial in position where it comes out of the calyx (Pl. VIIb. fig. 6, *x*).

At the level of the third radials of *Bathycrinus*, or the second brachials of *Rhizocrinus*, the circular course of the intestine is more apparent, and the plexiform gland is separated from the body-wall by the rectum, as shown in Pl. VIIb. fig. 7, and Pl. VIIIa. fig. 8. In both of these figures the *x* indicates the plexiform gland, which is here situated just below (*i.e.*, south of) the lower end of the fore-gut, where it passes into the mid-gut or intestine generally.

[1] Zur Anatomie des Rhizocrinus lofotensis, M. Sars, *Zeitschr. f. wiss. Zool.*, 1877, Bd. xxix. p. 64.

The further course of the rectum is shown in Pl. VIIb. fig. 8, which represents a section through the upper part of the disk at the level of the articulation between the first and second brachials; and the last trace of the plexiform gland (x) is seen between the fore-gut and the final coil of the intestine.

Both *Rhizocrinus* and *Bathycrinus* exhibit a peculiarity in the relations of the digestive tube and visceral mass which does not appear in the Pentacrinoid. The large crests at the sides of the arm-groove in the second brachials of *Rhizocrinus*, which were well figured by Sars,[1] have always been a puzzle to me, for they are something more than unusual developments of the muscle-plates at the distal end of the joint. Horizontal sections of the cup show, however, that they support the sides of comparatively large interradial diverticula from the intestinal coil, the outer ends of which are overlapped to some extent by the broad dorsal surfaces of the brachials (Pl. VIIIa. fig. 8).

The first traces of these extensions of the digestive cavity appear in *Rhizocrinus lofotensis* at the level of the muscle-plates of the first brachials, by which they are in a great measure supported. They become more independent of the skeleton at the syzygy with the second brachials; but enter into close relations with these joints at their distal ends, where the crests on the ventral surface become more prominent. They are much more marked in some individuals than in others, but the outline of the visceral mass is always distinctly pentagonal, even if its angles be not produced outwards, so as to give it a stellate appearance. The same peculiarity appears in *Bathycrinus*. The crests on the radial axillaries are large, wing-like processes, altogether distinct from the muscle-plates to which the first brachials are attached, as is shown in Pl. VII. fig. 4*a*, and Pl. VIIa. fig. 17; and they afford a large amount of support to the interradial diverticula of the gut (Pl. VIIb. fig. 7). These develop themselves gradually from below upwards, no trace of them appearing below the articulation of the second and the axillary radials; but indications of them are still visible at the upper part of the first brachials, as shown in Pl. VIIb. fig. 8.

In this figure, too, may be seen the earlier and simpler stages of that plication of the inner or adcentral wall of the gut which is so much more marked in *Pentacrinus*, and still more so in the Comatulæ, especially in *Antedon eschrichti*, *Promachocrinus*, and allied forms (Pl. LVIII. figs. 4–6).

The disk of the Comatulæ is generally flatter than that of the stalked Crinoids, and is almost entirely independent of any lateral support from the second radials. These lie beneath more or less of its dorsal surface, but do not protect its sides.

The descending portion of the fore-gut is therefore comparatively short, and the coiled intestine into which it passes lies spread out on the upper surface of the radials; so that there is no general dilatation of the gut at the bottom of the cup as in *Rhizocrinus*, *Bathycrinus*, and the Pentacrinoid. Some of the Pentacrinidæ approach *Antedon*, while

[1] *Op. cit.*, figs. 55–57.

others rather resemble *Rhizocrinus* and *Bathycrinus* in the arrangement of the digestive tube. *Pentacrinus decorus* is one of the latter. Even at the level of the radial axillaries the gut appears in section as a simple, but spacious cavity, with slight extensions at two points round the connective, or rather calcareous, tissue in which the plexiform gland is embedded. But it could hardly be called kidney-shaped, as it is in *Rhizocrinus* and *Bathycrinus*.

Some sections of a *Pentacrinus* disk, that were made for Sir Wyville Thomson by Dr. Stirling, show the indentation of one wall of the gut at the level of the radial axillaries by the plexiform gland and its surroundings to be considerably more marked than in *Pentacrinus decorus* (Pl. LVIII. fig. 4).[1] I am unfortunately unable to determine the species, as the sections were not properly labelled, and the series is not sufficiently complete for the purpose.

In *Pentacrinus wyville-thomsoni*, however, the condition of the gut is much more like that found in *Antedon*, which it further resembles in its disk being somewhat more independent of the skeleton than in other Pentacrinidæ. Even at the level of the second radials, a horizontal section of the disk shows a strong concavity at one side of the gut, which is thus almost crescentic in outline. The plications of the inner wall, however, are by no means so well developed as they are in many Comatulæ.

In the remarkable genus *Actinometra*, the radial centre of the water-vascular system does not correspond with that of the dorsal skeleton; and the curious duality of the Crinoid organisation is thus seen more distinctly in this type than in any other. The mouth is not sub-central but excentric, or even marginal (Pl. LXI. fig. 2), and there is no regular symmetry in the distribution of the ambulacra (Pl. LV. figs. 1, 2; Pl. LVI. fig. 7). The mouth may be radial, as in all endocyclic Crinoids, and such species of *Actinometra* as *Actinometra solaris*, *Actinometra pulchella*, and *Actinometra jukesi* (Pl. LV. figs. 1, 2); or it may be interradial, as in *Actinometra magnifica* (Pl. LVI. fig. 7); while in some types its exact position is difficult to determine. This is, however, immaterial as regards the course of the digestive tube, which proceeds directly downwards to a point somewhat behind and on the left (*east*) of the centre of the disk, and then commences to wind.

Its direction, just as in the endocyclic Crinoids, follows the watch-hand when seen from the ventral side; but there are four coils instead of one. This is shown in fig. 3, where the + at the end of the first coil marks the termination of that part of the gut which represents the whole digestive tube in the endocyclic forms.

This first coil occupies the extreme edge of the lowest part of the disk, and consequently passes in front of the mouth, so as to appear beneath it in longitudinal section (Pl. LXI. fig. 2). The second coil passes immediately behind it, and is followed by two more in an ever narrowing but ascending spiral, which terminates in the more or less central anal

[1] This figure nearly corresponds to the southeast corner of Pl. VIIb. fig. 7.

tube (Pl. LXI. fig. 1). This is often some little distance in front of the point where the lowest part of the long gullet turns off westwards to enter the great outside coil. The walls of this long digestive tube are tolerably simple and but slightly plicated. For an

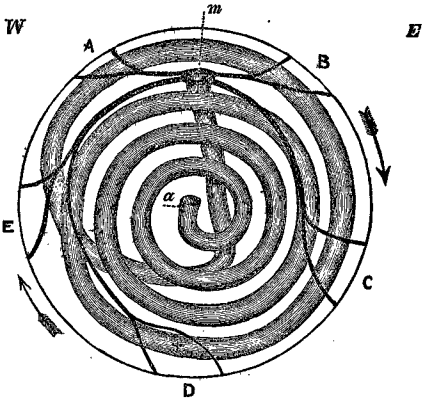


FIG. 3.—Diagram showing the course of the Digestive Tube in an *Actinometra* with Interradial Mouth, as seen from the ventral side.

Letters as in fig. 2. The + on the hinder portion of the outer coil indicates the limit of that part of the gut which corresponds to the entire digestive tube (excepting the rectum) of an endocyclic Crinoid.

extensive secreting surface is amply provided, without the necessity of this further complication, which is so largely developed in the simple spire of the gut in *Promachocrinus, Antedon eschrichti,* and *Antedon antarctica.*

C. THE WATER-VASCULAR SYSTEM.

The water-vascular system of a Crinoid consists, like that of the Stellerids, of an oral ring and radial vessels, the former being connected indirectly with the exterior through the intervention of the water-tubes, water-pores, and the body-cavity. Neither the oral ring nor the radial vessels have any ampullæ connected with them; though, as suggested by Ludwig,[1] these are perhaps represented by the small lateral pouches of the radial vessels which are opposite to the tentacular branches, and are crossed by muscle-threads[2] (Pl. LX. fig. 6).

The presence of these tentacular branches is invariably correlated with that of the food-groove. Where this is well marked, and lined by ciliated epithelium with the subjacent ambulacral nerve and blood-vessel, the water-vessels beneath the latter give off their branches to the tentacular groups in the usual regular way (Pl. Vc. fig. 7. Pl. LVII. figs. 1, 3, 4; Pl. LIX. figs. 1, 5; Pl. LX. figs. 1, 2, 6—*tb*; Pl. LXI. figs. 4, 6).

[1] Crinoideen, *loc. cit.*, p. 337.

[2] See also fig. 5 on p. 121, *m'*.

But if the food-groove on the ventral surface of the arm or pinnule remains undeveloped (Pl. LXI. fig. 3), not only are the ambulacral epithelium, nerve, and blood-vessel absent altogether, but the water-vessels are simple tubes like the integumentary water-vessels of the Molpadidæ, and have no lateral extensions, as tentacles are absent (fig. 4 on p. 113, *w*).

This condition may occur in a majority of the arms and even on the disk of *Actinometra* (Pl. LVI. fig. 7); on more or fewer of the lower pinnules of *Antedon acoela* and *Antedon angusticalyx* (Pl. LIV. figs. 1–3, 5); and on the proximal pinnules of *Antedon eschrichti* and *Antedon rosacea*, which receive no branches from the brachial ambulacra.

In *Metacrinus*, on the other hand, the ambulacra, and with them the water-vessels, of the large basal pinnules may start directly from the primary ambulacra of the disk, or even from the peristome itself (Pl. XXXIX. fig. 2; Pl. XLIII. fig. 3; Pl. L. fig. 2).

The radial water-vessels which underlie the disk-ambulacra of the Comatulæ pass off from the angles of the somewhat pentagonal water-vascular ring as single trunks, situated beneath the median lines of the ambulacra. But in *Pentacrinus*, at any rate in *Pentacrinus decorus* and *Pentacrinus wyville-thomsoni*, there is a radial extension of the labial blood-vascular plexus in this position (Pl. LVII. figs. 1, 3, 4, *lr*); and the two trunks which ultimately unite into the single water-vessel of the ambulacrum are thus kept separate from one another to a considerable distance, 1·5 mm. or more, from the edge of the peristome; that is to say, the angles of the water-vascular ring are produced in the direction of the rays, so that its outline is that of a short-armed *Asterias* rather than the more regularly pentagonal figure of a *Goniaster*.

The ciliated water-tubes ("Steincanäle," Ludwig) by which the water-vascular system communicates with the body-cavity, and thence with the exterior, vary very greatly in their development. The early Pentacrinoid has but one, situated in the same interradius as the fore-gut. In the later stages of Pentacrinoid life and in the young *Comatula* just free there are five, one in each interradius; and the same is the case in *Rhizocrinus lofotensis*. They are multiple in *Bathycrinus*, though not abundant; while in the adult *Antedon rosacea* there are about thirty in each interradius; and in *Antedon eschrichti* and in *Pentacrinus* the number becomes still larger (Pl. LVII. figs. 1, 3, 4; Pl. LIX. fig. 5—*wt*).

The radial water-vessels of *Comatula* commence as single trunks arising from the water-vascular ring at the edge of the peristome; and in a large *Comatula* like *Antedon eschrichti* the water-tubes may be found depending from the bases of the radial vessels beneath the middle line of the ambulacrum in the first two or three sections beyond the edge of the peristome.

In *Pentacrinus*, however, the middle line of the commencing ambulacrum is occupied

by the blood-vascular plexus (Pl. LVII. figs. 1, 4, *lr*), which has a water-vascular trunk on each side of it; and the water-tubes extend outwards in a radial direction as long as the water-vessels remain double. This is very evident in some horizontal sections through the upper part of the disk of *Pentacrinus naresianus*, which were made for Sir Wyville Thomson by Dr. Stirling. The double row of water-tubes may be seen extending along the sides of the ambulacra beneath the line of tentacles, to a distance of 3·5 mm. from the peristome, and then it is not complete.

The position of the water-tubes beneath the primary ambulacra is well shown in Pl. LVII. figs. 1, 3, 4. They are seen, as it were, coiling round the subambulacral plates to open below into the upper part of the circumvisceral coelom. When, however, the radial extensions of the labial plexus gradually thin out and the two lateral water-vessels unite into a single median trunk, the water-tubes become less numerous, and are only found in the first two or three sections beyond the point of union. They are thus really in the same position as in the Comatulæ, if we consider the double water-vessels as expressing extensions of the angles of the water-vascular ring in the direction of the rays.

The water-pores which pierce the ventral perisome, whether it be plated or not, are in a close functional relation with the water-tubes. They are the openings of minute canals which are lined by columnar epithelium, and expand almost immediately into enlargements where the epithelium is ciliated (Pl. LVII. figs. 1, 3, 4; Pl. LIX. figs. 2, 4, 6—*wp*). The inner end of the canal beyond the enlargement is lined by pavement epithelium, and opens into the body-cavity. According to Perrier[1] the primary water-tubes of the early larval Comatulæ are directly continuous with the inner ends of the water-pores, without the intervention of the body-cavity.

He has not yet figured this connection, however; and after the careful observations of Ludwig upon the subject, with which my own are in complete accordance, I have considerable hesitation in accepting Perrier's statements, especially as he admits that the water-pores of mature Comatulæ do establish communication between the body-cavity and the exterior, just as described by Ludwig in the Cystid phase. This subject is discussed more fully elsewhere.[2] [See Appendix, Note D.]

In the smaller and simpler types of Crinoids the water-pores correspond in number to the water-tubes. The young *Antedon* has one in each interradius; and the same is the case in *Rhizocrinus*, the single water-pore piercing the oral plate. In *Hyocrinus*, however, the number of pores is larger. In both the specimens which I have examined there are two pores in the oral plate of the anal interradius, and there are no others in any of the anambulacral plates which lie between it and the edges of the radials. In the other interradii the disposition of the water-pores is as follows:—

[1] Sur le développement des Comatules, *Comptes rendus*, t. xcviii., 1884, pp. 444–446.

[2] On some points in the Anatomy of Larval Comatulæ, *Quart. Journ. Micr. Sci.*, N. S., vol. xxiv., 1884, p. 320.

TABLE I.—*Water-pores of Hyocrinus.*

Interradius.	Oral Plates.		Anambulacral Plates.	
	A.	B.	A.	B.
No. 1[1] (anal), . . .	2	2	0	0
„ 2	0	?	2	4
„ 3	0	1	3	9
„ 4	0	1	3	7
„ 5	1	1	2	7

Thus, therefore, one specimen has all the oral plates perforated by water-pores, with one possible exception; while in the other it is only in the anal interradius and in the next one to it that the oral plate is pierced by a water-pore. It is significant that this interradius (No. 5) is that in which the primary water-pore appears in larval Asterids, Ophiurids, and Crinoids; and also that in both the specimens of *Hyocrinus* the water-pore is situated a little beyond the middle line of the large oral plate (Pl. Vc. fig. 6, *wp*), just as is the case with the single water-pore of the Pentacrinoid.

The disk of *Holopus* is practically entirely made up of the oral plates, and there is no ventral perisome at all. In the figure of these plates which was drawn for Sir Wyville Thomson by Mr. Black (Pl. III. fig. 2), each plate seems to be pierced by several pores; but as the specimen was further dissected after being drawn, and the oral plates were not preserved, I have been unable to satisfy myself upon this point.

The number of water-pores which may occur in any ordinary *Comatula* or *Pentacrinus* varies to a considerable extent. Ludwig estimates that there are 1500 in the ordinary adult *Antedon rosacea*, and there must be even more in *Antedon eschrichti*. Except in the immediate neighbourhood of the mouth they are less abundant in the anal interradius than elsewhere; and though they sometimes occur on the sides of the disk, *i.e.*, over the edge of the ventral surface, they never extend far down towards the dorsal side. When the disk is plated, the pores may be scattered singly in individual plates (Pl. XVII. fig. 6), or they may be grouped together on one plate, sometimes even to the number of twenty, as in *Pentacrinus decorus*.

In the exocyclic type *Actinometra*, the water-pores are generally situated in the immediate neighbourhood of the ambulacra; and the greater part of the disk which is occupied by the large anal interradius is almost entirely free from them. They are not necessarily limited to the disk, for they may also be found on the lower parts of the

[1] These numbers correspond to those which are employed by Ludwig in Asterid morphology.

arms and also on the proximal pinnules. In both cases they open into that section of the body-cavity which surrounds the generative apparatus, and is known as the genital canal (Pl. LXI. fig. 5). In a few cases too, I have found water-pores on the middle and later pinnules of the arms. They open into the genital canal of the pinnule, close to the point where it arises from that of the arm.

D. The Blood-Vascular System.

The foundation of almost all our accurate knowledge of the blood-vascular apparatus of the Crinoids is due to the researches of Ludwig. The blood-vessels form a highly complex system, parts of which are entirely unrepresented in the unstalked Echinoderms (*Echinozoa*); while other parts of it, such as the oral ring and its radial extensions above the water-vessels, conform to the ordinary Echinoderm type.

The radial vessels (Pl. VIIIa. figs. 4, 5; Pl. LIX. figs. 1, 5; Pl. LX. figs. 1, 4, 6—*b*) vary considerably in size, and are often invisible if the section be at all oblique. They are large in *Antedon eschrichti* and in *Actinometra nigra*, and may frequently be found to contain yellow pigment-masses or coagula. In the latter type they are sometimes triangular in section, with the apex pointing downwards so as to be received into a strongly marked concavity in the upper edge of the water-vessel (Pl. LXI. fig. 6); but in *Antedon eschrichti*, *Pentacrinus decorus*, and in most other types their section is more or less lenticular. Sometimes, however, it is triangular with the apex projecting upwards towards the epithelial layer above, and so rendering the ambulacral nerve much thinner in the middle line than in its more lateral portions (Pl. LX. figs. 1, 6, *b*).

Its cellular lining is much more delicate than that of the intervisceral blood-vessels, and is not easy to make out. Ludwig[1] found that this radial blood-vessel in the arms of *Antedon eschrichti* is sometimes divided into two parts by a vertical septum, which has a distinctly cellular covering; and I have not unfrequently found in the disk of the same species that the lumen of the vessel may be crossed in various directions by delicate threads with nuclei upon them. These resemble the nucleated muscle-threads in the water-vessels, but are much finer and less refractile.

The oral ring which connects the radial blood-vessels, and resembles them in structure, extends somewhat beyond the inner edge of the water-vascular ring (Pl. LXII.); and its wall thus projects into that part of the body-cavity which is contained within the dense mesh-work of connective tissue supporting the lip (Pl. LX. fig. 4, *c*). Ludwig has described in *Antedon rosacea* a number of more or less branching tubules which are connected with the oral blood-vascular ring, and have a somewhat better defined epithelial lining than the intervisceral blood-vessels.[2] He thought it possible that they might be in connection with the ramifications of the upper (ventral) end of the plexiform gland,

[1] Crinoideen, *loc. cit.*, p. 267.

[2] *Ibid.*, p. 328.

but he was unable to satisfy himself upon this point. The Naples variety of *Antedon rosacea*, upon which he worked, is about the worst type that could have been chosen for delicate observations of this kind, the quantity and character of the pigment-granules which the lip contains almost totally obscuring the other tissues.

This pigment-substance is altogether different from the yellow and brown pigment masses so common in all Echinoderms. It is apparently related to the calcareous spicules which are so abundant in the under part of the perisome and in the interviseral connective tissue. When these have been removed by acid their outlines are seen to be well defined by streaks of pigment-granules, which appear black by transmitted, and yellowish-white by reflected, light. They are especially abundant in the lip, and in some individuals almost entirely conceal the blood-vascular plexus which it contains;[1] while in specimens from other localities, and in *Antedon eschrichti*, it is scarcely developed at all, and I have found no difficulty in tracing the connection of the plexiform gland with the oral ring. This is very evident in all the other Comatulæ, including *Antedon*, *Actinometra*, and *Promachocrinus*, which I have examined, as well as in *Pentacrinus* (Pl. LVII. fig. 3; Pl. LXII.).

The branching tubules depending from the oral ring which much resemble the visceral blood-vessels, open into a dense plexus of more glandular looking tubules that is supported by connective tissue, and extends right round the lip (Pl. LVII. figs. 1, 3, 4; Pl. LIX. fig. 5; Pl. LX. figs. 1, 2, 4—*lp*).

It is connected with (1) the ventral branches of the plexiform gland (Pl. LVII. fig. 3, *xv*); (2) with the genital vessels of the rays (Pl. LX. figs. 1, 2, *gv*); and (3) with some of the intervisceral vessels (Pl. LVII. figs. 1, 3, 4; Pl. LX. figs. 2, 3, 5, *ib*; Pl. LXII.). These last form an extensive network over the coiled digestive tube, and are also directly connected with the plexiform gland (Pl. LVII. figs. 2, 5; Pl. LVIII. fig. 6, *ib*). This labial plexus is most abundantly developed beneath the south and south-east portions of the peristome, *i.e.*, in the neighbourhood of the left posterior ambulacrum. It lies between the hind-gut forming the last coil of the digestive tube, and that part of the capacious fore-gut which lies between the two lateral ambulacra of the right side. It is always pretty sharply defined from the surrounding connective tissue, and is usually a somewhat prominent object in a well-stained section which is examined with the naked eye or a simple lens. This is partly owing to the relatively thick walls of its component tubules, and partly to the delicacy of the connective tissue holding them together. Its relations are easily made out by the study of series of tranverse and longitudinal sections through the disk.

It is not very specially developed beneath the origins of the anterior and antero-lateral ambulacra, the plexiform genital vessels of which may be traced into it; though it is somewhat denser on the left (east) than on the right side, where it is connected

[1] I have found the same equally impracticable pigment in the disk of *Actinometra pectinata* from Singapore, and also in some individuals of *Actinometra parvicirra* from Bohol, although others from the same locality are totally devoid of it.

below with the plexiform gland rising alongside the fore-gut. But it is very marked indeed in transverse sections behind the mouth (*i.e.*, between it and the anus), as is well shown in the case of *Pentacrinus wyville-thomsoni* (Pl. LVII. fig. 1, *lp*), *Antedon eschrichti* (Pl. LX. fig. 5), or of any *Actinometra*. It gradually diminishes in size as the distance from the mouth increases, occupying an intermediate position between the two posterior ambulacra. It is usually rather nearer to the left one (*C*), but is sometimes closer to the other (*D*). The genital vessels of these ambulacra are derived from it (Pl. LVII. fig. 3; Pl. LX. figs. 1, 2—*gv*), and it finally passes insensibly into the intervisceral vesssels of the hinder part of the disk. In the specimen of *Antedon carinata*, one section of which is represented in Pl. LX. fig. 2, the labial plexus lies, as usual, rather nearer the left posterior ambulacrum, continuing very close and compact until just in front of the anal tube, where its meshes open out, and it passes into the ordinary network of intervisceral vessels.

In like manner the examination of a series of longitudinal sections shows that the labial plexus is denser, and extends farther from the peristome on the left side than it does on the right. In the specimen of *Antedon rosacea*, a section of which is figured in Pl. LIX. fig. 5, the plexus is much more developed, both anteriorly and posteriorly, at the left edge of the mouth-slit than at the right edge, or even than in the median plane which traverses the anterior ambulacrum. The section figured (Pl. LIX. fig. 5) passes through the left angle of the peristome, from which the two lateral ambulacra diverge; and the labial plexus is seen as a broad band (*lp*), which lies between the water-tubes depending from the water-vascular ring (*wt*), and the fore-gut (*fg*); it diminishes in size as the distance from the mouth increases, and loses its individuality when the two ambulacra become differentiated.

Unfortunately I do not know the locality of this specimen; but it is singularly devoid of the dichroic pigment which so unpleasantly increases the difficulty of accurate observation in the Naples variety of *Antedon rosacea*.

In *Promachocrinus kerguelensis*, in *Antedon eschrichti* and its allied species *Antedon quadrata* and *Antedon antarctica*, a portion of the labial plexus between the mouth and the anal tube differs very considerably in structure from the rest of this organ. The limits of this portion are so well defined, and it differs so much from the remainder of the labial plexus, that I propose to designate it by the name "spongy organ." Its relations to the rest of the labial plexus in *Antedon eschrichti* are shown in Pl. LX. figs. 3, 5, *so*. The former represents a longitudinal, and the latter a transverse section of it; while in Pl. LIX. fig. 8, a portion of the spongy organ of *Promachocrinus kerguelensis* is shown more highly magnified. It lies between the mouth and anus on the left or eastern side of the gullet, and therefore is slightly nearer to the left posterior than to the right posterior ambulacrum.

In its most fully developed condition, only found between the mouth and anus, the

spongy organ is a somewhat egg-shaped mass, consisting almost entirely of a delicate network of connective tissue with more or less open meshes.

The latter are rather wider in *Promachocrinus* than in any other Crinoid which I have examined. The trabeculæ forming its outer portion are much more delicate than those nearer the surface; and I have been unable to make out that they possess any epithelial covering. The surface of the organ, however, is more compact, with larger trabeculæ and generally smaller meshes. These are lined by epithelial cells, being in fact the ends of those blood-vessels forming the labial plexus which are connected with the spongy organ, mostly, if not entirely, on its ventral side (Pl. LX. fig. 5).

Some of these vessels are seen in more or less oblique section at the right end of the spongy organ of *Promachocrinus kerguelensis* (Pl. LIX. fig. 8), while the relation of the spongy organ to the labial plexus generally is well shown in the transverse and longitudinal sections through the disk of *Antedon eschrichti* (Pl. LX. figs. 3, 5). The spongy organ of this species is more compact than that of *Promachocrinus*. It is similarly situated in the space left by the incomplete adhesion of the visceral and parietal layers of the peritoneum; and it is suspended in this space by threads of connective tissue. It is practically the direct backward continuation of the labial plexus at the eastern angle of the mouth, where it is much more largely developed than on the opposite side. The relatively thick epithelial wall of the vessels gradually disappears as they enter the spongy organ; while the latter in its turn passes insensibly backwards into the plexus of vessels on the upper surface of the visceral mass, from which are derived both the intervisceral vessels and the genital vessels of the two posterior ambulacra. The absence of an epithelial lining in the spaces of the spongy organ is very marked, although the epithelium is quite distinct in the blood-vessels which terminate therein. But, on the other hand, I have found, both in this species and in *Antedon quadrata*, that the nuclei of the connective tissue forming the trabeculæ stain very prominently, much more so than I could get them to do in *Promachocrinus kerguelensis*.

Although the simple reticular structure of the spongy organ in this latter type is limited, as described above, to that part of the labial plexus which is situated between the mouth and anus, yet the distinction between it and the remainder of the labial plexus is far less sharp than in *Antedon eschrichti*. For the vessels forming the labial plexus of this type are much more closely grouped, and have a less definite epithelial wall than is the case in *Antedon eschrichti*, so that it assumes a decidedly reticular character. This is also the case with the upper end of the plexiform gland, which retains its individuality till quite close to the mouth (Pl. LIX. fig. 9, *xv*), for it remains large and lobulated, instead of breaking up as in *Antedon*; and the connection of its reticular portion with the labial plexus at the north-east angle of the mouth is quite distinct; while at the western angle the labial plexus, though somewhat reticular in structure, is but poorly developed.

Towards the hinder edge of the mouth the trabecular structures in the left division of the labial plexus become more and more delicate, their cellular covering thins out, and the true spongy organ appears, with the characters described above. It is formed almost entirely from the network on the left side of the mouth in which the plexiform gland ends (Pl. LIX. fig. 9, *xv*). It remains throughout nearer to the left than to the right of the two posterior ambulacra, gradually becoming more compact again, and finally passes into the plexus of intervisceral and genital vessels.

The spongy organ of the type which is generally called *Antedon rosacea* varies very much in its structure. In some cases it is almost as reticular as in *Antedon eschrichti*, while in others it is hardly differentiated from the rest of the labial plexus, and consists of a mass of twisted tubules, which have well defined epithelial walls. It is possible that these variations may be due to specific differences, but upon this point I can, as yet, offer no opinion.

The labial plexus of *Pentacrinus*, at any rate of the two species which I have studied (*Pentacrinus decorus* and *Pentacrinus wyville-thomsoni*), is much more highly developed than in the Comatulæ, but it contains nothing like the spongy organ of *Antedon eschrichti* and its allies. It extends outwards for some little distance from the peristome, both beneath and between the ambulacra. In the former case it is connected with the radial blood-vessels, beneath the middle line of the groove, thus keeping apart the converging water-vascular trunks at its sides as already described (Pl. LVII. figs. 1, 3, 4, *lr*).

Its histological condition in the individuals of both the species which I have examined is not such as to facilitate the observation of minute structural details, but from what I have seen of the better preserved portions of it, I have no reason to think that it differs essentially from the corresponding organ in *Antedon*. The epithelial lining of its cavities is often fairly distinct, as shown in Pl. LVII. fig. 4.

As the ambulacra recede from the peristome and thus diverge more and more, the vascular plexus underlying the interpalmar area which separates them gradually thins out, until it is only represented by the uppermost intervisceral vessels and the genital vessels of the rays, both of which originate in it. The former belong to the circumvisceral layer of the peritoneum, and the latter to the parietal layer; but the two systems are in free communication with one another (Pl. LVII. fig. 3, *gv*, *ib*).

The tubules depending from the radial blood-vessel and entering the subambulacral plexus gradually become less and less abundant, and finally disappear altogether, shortly before the limit of the water-tubes is reached. In the anal interradius the labial plexus is specially developed, as is well shown in transverse section in *Pentacrinus wyville-thomsoni* (Pl. LVII. fig. 1, *lp*), lateral extensions of it being connected with the radial blood-vessels by the tubules above mentioned. [See Appendix, Note D.]

The subdivision of the upper end of the plexiform gland into numerous branches which terminate in the labial plexus, can generally be made out without any difficulty

in vertical sections of a disk that is moderately free from pigment. In none of the species of *Pentacrinus* or *Comatula* which I have examined, have I failed to observe this connection satisfactorily; and in some fortunate sections the vascular structure may be traced right down from the oral ring into the lower and more compact portion of the plexiform gland (Pl. LXII.). This is generally more or less lobulated in form, and in this respect very striking differences exist among the various types of Crinoids.

Both in *Rhizocrinus* (Pl. VIIIa. figs. 7, 8, *x*), and in *Bathycrinus* (Pl. VIIb. figs. 1, 4–8, *x*) it is almost as simple as in the Pentacrinoid. It is oval-oblong in section and has but slightly developed irregularities of outline. In *Antedon rosacea*, and in the lower part of the disk of *Pentacrinus*, until it commences to subdivide, it is more irregular in form (Pl. LVIII. fig. 4, *x*); and it shows indications of its lobular structure, as is well seen in Ludwig's admirable illustrations [1] of the former type. I have made no horizontal sections of the disk of *Antedon eschrichti*, but imagine that its plexiform gland must be not very unlike that of *Promachocrinus kerguelensis*. Figs. 5 and 6 on Pl. LVIII. represent horizontal sections through the gland in the lower half of the disk of this type, fig. 6 being that nearer the calyx. The irregularity in the form of the organ is very striking. The upper part of the same disk was cut into vertical sections. They show the extreme subdivision of the ventral end of the plexiform gland, and the termination of its branches in the well defined labial plexus, the spongy part of which is represented in Pl. LIX. fig. 9, *xv*.

The minute structure of the plexiform gland of the Crinoids is as yet unknown. According to Perrier [2] it is identical with that of the same organ in other Echinoderms. Fresh specimens, and not spirit-material, are absolutely essential for its elucidation; but as Perrier and Koehler, who have both studied the plexiform gland of the Urchins, give accounts of its structure which differ from one another, and from Apostolides' description of the same organ in Ophiurids, there is a difficulty in determining from analogy, and still more so from observation, what its real nature is in Crinoids.[3] Certain peculiarities that I have noticed in the appearance of its lower portion in *Pentacrinus decorus* lead me to think that Koehler's account of it in the Urchins [4] is probably more correct than those of his fellow-workers.

Upon one point, however, I am quite satisfied. Although the condition of my material entirely precluded any minute observations on the structure of the plexiform gland, I have had no difficulty in tracing its connection with the intervisceral blood-vessels of the lower part of the disk (Pl. LVII. fig. 2, Pl. LVIII. fig. 6). This point was first noticed by Ludwig in *Antedon rosacea*, and he illustrated it with an excellent figure.[5] I have

[1] Crinoideen, *loc. cit.*, Taf. xviii. figs. 57–59.

[2] Sur l'organisation des Crinoïdes, *Comptes rendus*, t. xcvii., No. 3, p. 18.

[3] For a discussion of this subject see *Quart. Journ. Micr. Sci.*, N. S., vols. xxii.–xxiv., 1882–1884.

[4] Recherches sur les Échinides des Cotes de Provence. *Ann. du Mus. d'Hist. Nat. de Marseille*, t. i. pp. 73–77, 95–99.

[5] Crinoideen, *loc. cit.*, Taf. xviii. fig. 59.

142603

myself described and figured the same connection in *Actinometra parvicirra*;[1] and I have since seen it so frequently in the different species which I have studied, that I read the following statement of Perrier's with some little surprise. Speaking of the plexiform gland of *Antedon rosacea*, he says,[2] "Les vaisseaux qui paraissent en partir ne sont autre chose que les ramifications de la glande, se terminant d'ordinaire par des renflements ayant l'aspect de culs-de-sac. Ces ramifications courent au milieu des innombrables trabécules du tissue conjonctif de la cavité générale, qui peuvent eux mêmes parfois prendre l'apparence des vaisseaux." I cannot gather from this passage whether Perrier means to deny the existence of intervisceral vessels altogether, or merely the connection of this system with the plexiform gland. I have good reason to believe, as pointed out elsewhere,[3] that his statements refer solely to *Antedon rosacea*; but even in this unfavourable type I have had no difficulty in confirming Ludwig's observations respecting the relations of this organ to the blood-vessels. If the latter be ramifications of the gland, as Perrier asserts, one would expect that they should have the same structure as it; whereas their nature is the same as that of the intervisceral blood-vessels, which are lined by a layer of pavement-epithelium (Pl. LVII. fig. 5); while their apparent blindness is simply due to the impossibility of any single section showing more than a very small portion of their winding course. A careful study of a good dissection, or of a moderately thick transparent section, especially with a binocular, or an accurate plotting out on paper of a series of thin sections by means of a camera, will reveal much that is totally unrecognisable in other ways. [See Appendix, Note E.]

I have studied the intervisceral blood-vessels principally in *Antedon eschrichti*, *Pentacrinus decorus*, and *Actinometra parvicirra*. In the *Pentacrinus*, with its body-cavity reduced by the presence of much calcareous tissue, the visceral blood-vessels are less abundant within the simple coils of the digestive tube than on its outer surface, where they may be excellently seen in tangential sections of the visceral mass, as shown in Pl. LVII. fig. 5, *ib.*

But in *Antedon eschrichti* and *Actinometra*, which have a more complex digestive tube, the intervisceral blood-vessels are more largely developed. The connection of one of them with the plexiform gland of *Promachocrinus kerguelensis* is shown in horizontal section in Pl. LVIII. fig. 6, while Pl. LVII. fig. 2 represents a portion of one of several vertical sections of *Pentacrinus decorus* in which the same point is visible, the plexiform gland itself unfortunately having no recognisable structure.

The blood-vessels may be readily distinguished from connective tissue, especially in *Pentacrinus*; for nearly all the visceral connective tissue of this type is regularly calcified,

[1] The Minute Anatomy of the Brachiate Echinoderms, *Quart. Journ. Micr. Sci.*, N. S., vol. xxi., 1881, p. 185, pl. xii. figs. 14, 15.

[2] *Comptes rendus*, t. xcvii. p. 188.

[3] Notes on Echinoderm Morphology, No. VI.; On the Anatomical Relations of the Vascular System, *Quart. Journ. Micr. Sci.*, 1883, vol. xxiii. p. 610.

and therefore presents the usual reticular structure after the limestone has been removed; and even those bands of ordinary connective tissue (both in Comatulæ and in *Pentacrinus*) which contain irregular limestone deposits have a totally different facies from the blood-vessels (Pl. LVII. fig. 5). They meet at different angles, and have no internal cavity which is lined by epithelium and frequently contains coagulum.

The relation of the plexiform gland to the intervisceral blood-vessels is especially well seen in *Actinometra*.

Owing to the excentric position of the mouth, the characters of the plexiform gland are considerably different from those of the same organ in the regular Crinoids. I have studied it more particularly in the two species *Actinometra parvicirra* and *Actinometra pulchella*, the latter having the mouth much nearer to the centre of the disk than the former. It is also radial in position, while that of *Actinometra parvicirra* is interradial. In both types the labial plexus is most developed behind the mouth, and especially towards the left or eastern angle, where it contains an imperfectly differentiated spongy organ; and it also extends outwards between the ambulacra farther than on the right side.

It is the right anterior portion of the labial plexus, however, which is more especially connected with the plexiform gland, while the spongy organ at the left posterior angle of the mouth passes backwards into the intervisceral vessels.

In *Actinometra pulchella* with its radial, and but slightly excentric mouth (Pl. LXI. fig. 1), the relations of the parts are, as might be expected, much more like those of *Antedon* than is the case in *Actinometra parvicirra*, with its nearly marginal and interradial mouth (Pl. LXI. fig. 2). In the former type the plexiform gland rising out of the calyx ascends nearly in the vertical axis of the disk for some little distance and then divides into two principal portions. The left hand one is little more than a bundle of vessels which runs forwards, upwards, and a little outwards till it comes to lie above the gullet immediately in front of the base of the anal tube, and terminates in the spongy part of the labial plexus at the left posterior angle of the mouth. The right division, which is connected with the intervisceral vessels of the anterior half of the disk, retains its glandular character, and passes upwards between the coiled gut and the central rectum to join that part of the labial plexus which lies beneath the origins of the ambulacra of the right side.

The fore-gut of *Actinometra parvicirra* passes more directly backwards and downwards than that of *Actinometra pulchella*, until it comes to lie immediately above the base of the posterior ray, rather to the left of the centre of the disk (Pl. LXI. fig. 2). The spongy organ at the left posterior angle of the mouth is continued downwards and backwards slightly above the gullet, between it and the three inner coils of the gut, as a gradually diminishing bundle of vessels, with which the intervisceral vessels of the left half of the disk are connected. This corresponds to the left division of the plexiform gland in *Actinometra pulchella*, though not quite in the same position as regards the digestive

tube. It is connected with the plexiform gland proper by numerous intervisceral vessels, which pass both above and below the fore-gut so as to completely surround it.

The plexiform gland proper bends directly forwards as soon as it enters the visceral mass, lying at first a little way from the right end of the gullet, but ultimately comes to be close to its anterior end.

This is more nearly in the median longitudinal plane of the disk, so that the plexiform gland lies between the gullet and the first or outside coil of the gut; and as in *Actinometra pulchella*, the glandular structure passes directly into the labial plexus at the right angle of the mouth.[1] It does not therefore, as in the more regular forms, directly give off the œsophageal bundle, being only in connection with it by the intervisceral vessels which encircle the gullet; but it is the centre for all the vessels of the right and anterior sides of the disk, just as the corresponding structure is in *Actinometra pulchella*.

The plexiform gland diminishes gradually in size when it has passed out of the visceral mass into the central funnel within the radials; and it begins to lose its glandular, more or less lobulated appearance (Pl. XXIV. fig. 9, *X*). This is retained longer in forms like *Bathycrinus* and *Rhizocrinus*, which have relatively high radials (Pl. VIIb. figs. 3–5; Pl. VIIIa. fig. 7—*x*). Vascular cavities begin to appear in it and group themselves into an inner set surrounded by a ring of five vessels, which are radially disposed. These expand within the basals into the chambers of the chambered organ (Pl. VIIb. fig. 2; Pl. XXIV. figs. 6–8; Pl. LVIII. figs. 1–3—*ch*). Ludwig has given an excellent account of this connection in *Antedon rosacea*,[2] which applies equally well to *Actinometra*, *Rhizocrinus*, *Bathycrinus*, and *Pentacrinus*.

According to Perrier,[3] however, "Le corps ovoïde s'implante chez la Comatule adulte sur l'un des planchers horizontaux de l'organe cloisonné." In this, as in the former case, I am at a loss to make out Perrier's real meaning. For he admits in a later communication[4] that the ovoid gland or axial organ terminates below "en un tube conique qui pénètre, en s'amincissant toujours, dans l'axe de l'organe cloisonné;" and that this tube is the upward continuation of the cellular "cordon" in the centre of the larval stem.

If, however, he intends to deny the communication of the cavities of the chambers with those of the plexiform, or, as he calls it, the "ovoid" gland, I must totally disagree with him. For I have the most satisfactory evidence of this connection in my series both of horizontal and of vertical sections through these structures in *Pentacrinus decorus*, and also in other types.

The upper part of the stem contains the usual six vessels, five peripheral and one central (Pl. XXIV. figs. 2, 5; Pl. LVIII. fig. 3). The single axial vessel which represents Perrier's "cordon central" in the larval stem divides when it enters the chambered

[1] Two figures, illustrating these points in *Actinometra parvicirra*, will be found in the *Quart. Journ. Micr. Sci.*, N. S., vol. xxi., 1881, pl. xii. figs. 14, 15.

[2] Crinoideen, *loc. cit.*, p. 317.

[3] *Comptes rendus*, t. xcvii. p. 188.

[4] *Comptes rendus*, t. xcviii. pp. 445, 446.

organ, first into two (Pl. XXIV. fig. 6, *v*), and then into four or more; while the peripheral vessels around it expand into the chambers (Pl. XXIV. figs, 6, 8; Pl. LVIII. figs. 1–3—*ch*), just as they do on a smaller scale within the nodal stem-joints (Pl. XXIV. fig. 4, *chn*).

As the ascending vascular axis of *Pentacrinus decorus* passes out of the basal ring, and enters the central plug within the radial pentagon, the chambers become elongated and pear-shaped in the direction of the rays; and at the same time their cavities are traversed by trabeculæ, which break them up into numerous smaller cavities that contain masses of yellowish-brown pigment-granules (Pl. LVIII. fig. 2, *ch*). Some of these spaces have a definite epithelial lining, like the chambers with which they are connected, while others are deficient in this respect. Before reaching the level of the circular commissure, however, these radial extensions of the outer vessels of the plexiform gland terminate somewhat abruptly; and the gland is reduced to a small but compact bundle of vessels in the middle of the central plug.[1] As it rises it becomes extended laterally, and its shape when it enters the visceral mass (as seen in section) is that of a more or less irregular L; while this soon passes into a lobular form of the usual variable character.

The appearance of these radial extensions of the lowest part of the plexiform gland in *Pentacrinus decorus* forcibly recalls Koehler's description of the minute structure of the ventral end of the ovoid (plexiform) gland in the Urchins. This is connected with the oral ring by a single vessel, which is called by Koehler the glandular canal. The other end of the gland is said by the French anatomists to open externally through the madreporite in all the Echinozoa, together with the water-tube; though both in Asterids and in Ophiurids Ludwig has described it as connected with an aboral vascular ring in which the genital vessels arise, and there is strong reason to believe that the same is the case in the Urchins too.

It will be a matter of no little difficulty to determine exactly the portions of the blood-vascular system of a Crinoid which are represented in a Starfish or Urchin; and the question will probably only be satisfactorily settled by careful studies in organogeny. There is no doubt about the oral ring upon the one side of the disk, and the chambered organ on the other. But where is the line to be drawn between the two?

It seems to me not unlikely, as I have suggested elsewhere,[2] that the labial plexus of Crinoids may represent the aboral ring of the Echinozoa, the plexiform gland being much shortened, but expanded laterally instead. Both the intervisceral and the genital vessels are in communication with it, just as they are with the aboral ring of Asterids, according to Ludwig; and in this class too the plexiform gland is continued upwards beyond the

[1] The upward passage of the chambers into the peripheral cavities of the lower part of the gland is better shown in the section next to that represented in Pl. LVIII. fig. 2.

[2] *Quart. Journ. Micr. Sci.*, N. S., vol. xxi., 1881, p. 185; and also Notes on Echinoderm Morphology, No. V.; On the Homologies of the Apical System, with some Remarks upon the Blood-vessels, *Ibid.*, N. S., vol. xxii., 1882, p. 375.

aboral ring to terminate in the perisome of the central part of the disk. It would be very interesting to determine the relation of this dorsal extension of the plexiform gland in those Asterids such as *Zoroaster fulgens*, which retain well-developed basal and radial plates in the centre of the disk, so as to resemble the calyx of a Crinoid.[1]

It will be remembered that Prof. Perrier has noted the identity in structure between the axial organ of a Crinoid and the so-called ovoid gland of the Echinozoa. This organ is considered by Ludwig and myself to be in a close relation with the blood-vascular system, and intimately united to the oral blood-vascular ring, just as the axial organ is in the Crinoids. But Perrier believes it to be an excretory gland, unconnected with the blood-vascular system and opening to the exterior through the madreporite. Koehler's observations on the Urchins, however, tend to disprove this theory, as I have shown elsewhere.[2] Perrier has recently asserted that the axial organ of a Crinoid communicates with the exterior (see Appendix, Note D); but although he has described its structure as identical with that of the ovoid gland of Starfishes and Urchins, he nevertheless compares it with the madreporic or stone-canal of these types.[3] He thus considers an organ which is related to the blood-vascular system of a Crinoid to be represented by a part of the water-vascular system of other Echinoderms; and he denies that the latter corresponds to the water-tubes and water-pores of a Crinoid, as is generally supposed.

The only reasons which he brings forward for this conclusion are that the walls of the axial organ in the young Crinoid are folded like those of the stone-canal in Starfishes; while it has the same position with regard to the digestive apparatus as the stone-canal of Urchins. The first reason appears to me to be of very little value, as I have pointed out elsewhere;[4] while Perrier seems to have overlooked the fact that the second one is equally applicable to the doctrine of a general homology between the axial organ of a Crinoid and the so-called heart of an Urchin. For this structure lies in the immediate neighbourhood of the stone-canal, and Perrier himself admits that it is identical in structure with the axial organ of a Crinoid, which is certainly not the case with the stone-canal.

It is difficult to see what rational grounds Perrier has for his suggestion that a part of the water-vascular system of a Starfish or Urchin is represented by an organ which belongs to the blood-vascular system of a Crinoid, as his own observations show, though he nowhere admits that such is the case. (See Appendix, Note F.)

The chambered organ of *Comatula* is contained within the cavity of the centro-dorsal, and is covered in above by the rosette of metamorphosed basals; it is a larger structure, both relatively and absolutely, than that of a stalked Crinoid, owing to the concentration of the cirri at the top of the larval stem.

[1] See Sladen, On the Homologies of the Primary Larval Plates in the test of Brachiate Echinoderms, *Quart. Journ. Micr. Sci.*, 1884, vol. xxiv., N. S., pp. 32–34, pl. i. fig. 16.

[2] *Quart. Journ. Micr. Sci.*, 1883, vol. xxiii., N. S., pp. 599–609.

[3] *Comptes rendus*, t. xcviii. pp. 445, 446.

[4] *Quart. Journ. Micr. Sci.*, 1884, vol. xxiv., N. S., p. 323.

In *Bathycrinus*, *Rhizocrinus*, and *Pentacrinus* the central vascular axis of the stem consists of five peripheral vessels surrounding a core of smaller ones (Pl. VIIa. fig. 2; Pl. XXIV. figs. 2, 5; Pl. LVIII. fig. 3—*ch'*); and from these peripheral vessels are derived the central vessels of the cirri borne by the stem. In *Pentacrinus* these cirri are borne by special nodal segments which occur at more or less regular intervals all down the stem. The five large peripheral vessels expand slightly in each nodal joint, and each gives off one cirrus-vessel (Pl. XXIV. figs. 3, 4, *chn*, *cv*; Pl. LXII.). Hence, every nodal joint contains, as it were, a small edition of the chambered organ situated in the calyx (Pl. XXIV. figs. 6, 8, *ch*; Pl. LXII.).

In *Comatula*, however, the centro-dorsal represents physiologically "a coalesced series of the nodal stem-joints in the stalked Crinoids,"[1] and the downward prolongations of the chambers into the stem are ruptured when this organ is discarded. A minute opening in the floor of each chamber close to the central axis remains to indicate their former existence, while a small aperture in the middle of the peripheral wall of the chamber leads into a cirrus-vessel. The vessels of the remaining cirri are derived from those forming the central axis of the chambered organ. They pass outwards horizontally beneath the chambers in five groups which are thus radial in position, as are the earlier cirri and those on the stem of *Pentacrinus* (Pl. XXIV. fig. 4, *cv*; Pl. LXII.).

In *Actinometra parvicirra*, the only species of the genus in which I have made horizontal sections through the calyx, the central axis of the chambered organ contains only two vessels, instead of the larger number present in *Antedon rosacea*; and there are fewer cirrus-verticils beneath the chambers. This is only what might have been expected, from the reduced size of the centro-dorsal in this type and the small number of cirri which it bears. In the Pentacrinoid again, with an undeveloped centro-dorsal bearing only five cirri, the vessels of these organs are derived directly from the cavities of the chambers, just as in the nodal joints of the stem of *Pentacrinus*.

Perrier has described the cirrus-rudiments as originating from the "cordon central" of the larval stem, and as alternating with the rays, *i.e.*, as interradial in position.[2] He has given no figures in support of his statements, which are far from being in accordance with the observations of M. Sars, Dr. Carpenter, and myself, as I have explained elsewhere.[3]

The smaller size of the cavities of the chambered organ in the stalked Crinoids than in the Comatulæ, and the greater simplicity of its central axis, are obviously related to the absence of a cirrus-bearing centro-dorsal.

Both in *Rhizocrinus* and *Bathycrinus*, so far as my experience goes, the axis of the chambered organ is formed throughout of a single vessel (Pl. VIIb. fig. 2, *V*). In *Pentacrinus* there is only a single vessel in the upper part of the stem (Pl. XXIV. figs. 2–5, *V*).

[1] Wyville Thomson, *Phil. Trans.*, 1865, p. 536.

[2] *Comptes rendus*, t. xcviii. pp. 445, 446.

[3] *Quart. Journ. Micr. Sci.*, 1884, vol. xxiv., N. S., pp. 325, 326.

This divides into two or more which pass upwards, like the chambers themselves into the glandular organ above (Pl. XXIV. fig. 6; Pl. LVIII. fig. 3—*V*; Pl. LXII.). But a sieve-like axis, such as occurs in *Antedon*, is absent in the stalked Crinoids, which have no cirri just beneath the calyx that require to be supplied with blood.

E. The Genital Glands.

Since the discovery, made independently by Dr. Carpenter and Prof. Semper,[1] that the so-called nerve of Müller, which is situated between the skeleton and the water-vessel of the Crinoid arm, is really a part of the generative system, our knowledge of its minute anatomy has been largely increased by Ludwig.

He discovered that the actual genital tube, the epithelial cells of which develop into ova (Pl. Vb. fig. 1; Pl. Ve. fig. 1; Pl. VIIIa. figs. 4, 5; Pl. LX. fig. 6—*gc.*), is suspended by fusiform or branched cells within a blood-vessel; and he believed this vessel to arise from the vascular plexus underlying the subtentacular canals of the disk.

Dr. Carpenter had previously come to the conclusion, as the result of his dissections, that the genital cord or so-called rachis of the arm is a radial extension of this plexus. He further believed the latter to be in connection with the ventral end of the plexiform gland, having seen the division of this organ in the Pentacrinoid into five branches, one of which passes to each ray, an observation which may be easily confirmed by examination of optical sections of a Pentacrinoid, soon after the appearance of its first whorl of cirri. According to Perrier the body-cavity of a mature Pentacrinoid or recently liberated *Comatula* contains no structures which could be considered as blood-vessels; although he finds within the meshwork of connective tissue that occupies the body-cavity "un petit nombre de cordons cellulaires pleins qui se rendent manifestement aux bras"[2] I have little doubt that these are a further development of the branches from the axial organ of which one passes to each ray, as described by Dr. Carpenter; and that they eventually give rise to the subambulacral plexus of genital vessels (Pl. LVII. fig. 3; Pl. LX. figs. 1, 2—*gv*).

The genital tube of the arm is regarded by Ludwig as a sterile portion of a complex genital organ,[3] the epithelial lining of which only develops into ova or spermatozoa in particular places, usually within the pinnules. The cells lining it are relatively large, and project into its interior, thereby reducing its cavity very considerably.

Dr. Carpenter, who was unacquainted with the blood-vessel ensheathing the true genital cord, spoke of the latter as having a tubular wall and granular contents;[4] and he stated that in the plexus beneath the subtentacular canals of the disk of *Antedon rosacea*

[1] Kurze anatomische Bemerkungen über Comatula, *Arb. zool.-zootom. Inst. Würzburg*, Bd. i. p. 260; translated, with an Addendum by Dr. Carpenter in the *Ann. and Mag. Nat. Hist.*, ser. 4, vol. xvi., 1875, pp. 202–209.

[2] *Comptes rendus*, t. xcviii. p. 445.

[3] Crinoideen, *loc. cit.*, p. 293.

[4] *Proc. Roy. Soc. Lond.*, 1876, pp. 220, 221.

the cavity with its granular contents bears a smaller proportion to the thickness of the tubular wall. I suspect that this varies somewhat according to the sexual maturity of the individual; but I have generally noticed that the vessels of this plexus in *Antedon eschrichti* do not show such a clear section as the visceral blood-vessels, their lumen being occupied by cellular structures; while in some disks of this species I have found as distinct a genital tube within the vessels of this subambulacral plexus as is to be met with in the arms between the bases of two successive pinnules.

Further, in one example of *Antedon rosacea*, I found a small but well-developed ovary occupying the position of the genital plexus beneath the left posterior ambulacrum of the disk. The first traces of it appear in the sections which pass through the hinder part of the spongy organ; and it extends outwards to the point where the primary radial groove divides into the two which proceed to the arms. It contains the nuclei of half a dozen ova in various stages of development, some with a germinal spot, and some without.

A still larger and more fully developed ovary occurs in the disk of one of the three examples of *Actinometra pulchella* which I have cut into sections. It commences close to the peristome, and extends outwards beneath the left anterior ambulacrum nearly to its bifurcation, lying close down upon the upper surface of the intestine, and moulded to the plications of its wall.

In *Antedon carinata* I have not only found a distinct genital tube within some of the vessels forming the plexus beneath the disk ambulacra, but I have also met with detached portions of ovaries containing more or less fully developed ova in various parts of the body-cavity, *e.g.*, in the spaces of the connective-tissue network forming the lip; in the intervisceral portion of the body-cavity, between the two parts of the coiled gut; and in the subtentacular canals between the genital plexus and the water-vessels.

There can, therefore, I think, be hardly any question as to the relation between the genital glands and portions of the blood-vascular system; while the occasional development of rudimentary ovaries within the disk of recent Crinoids is of considerable importance. For it shows that there is no morphological improbability in the theory which supposes the genital glands of extinct armless types, like the Blastoids and Cystids, to have been situated within the body, rather than in the so-called pinnules, even when these are present, which is by no means always the case.

The fertile intra-pinnular portions of the genital glands vary considerably in shape. In most of the British varieties of *Antedon rosacea*, in *Antedon angusticalyx*, *Antedon acoela*, and *Eudiocrinus japonicus*, they are short, thick, and rounded. They sometimes terminate in rounded ends, and are sometimes continued onwards as slender cords through two or three pinnule-joints. But in the *Antedon rosacea* from Naples, and in the group of species allied to *Antedon eschrichti*, they are long and fusiform, extending over several pinnule-joints. The same is the case in *Hyocrinus* (Pl. Vc. figs. 8, 10, *t*), *Bathycrinus* (Pl. VII. fig. 7; Pl. VIII. fig. 5), and *Rhizocrinus* (Pl. X. fig. 20), though to

a less extent. The ovaries of the Pentacrinidæ are likewise long and fusiform, some of them appearing to present somewhat anomalous characters. For in some sections which were made for Sir Wyville Thomson by Dr. Stirling, the ovary appears in the arm, occupying the usual position between the subtentacular and the cœliac canals where the sterile genital cord is normally found. This is also the case in the lower parts of the arms of *Holopus* (Pl. Vc. fig. 2, *ov*), but I have not yet succeeded in discovering which species of *Pentacrinus* or *Metacrinus* is distinguished by this peculiarity; for the sections above mentioned were not labelled with any name or reference number. I have cut sections of the arms of all the more common Pentacrinidæ, but in none of them have I found any such departure from the type of the ordinary *Antedon* as is presented by the ovaries of this unknown species.

Many years since it was discovered by Prof. Semper,[1] during his residence in the Philippine Islands, that the ovaries of *Actinometra parvicirra* (=*Actinometra armata*, Semper, M. S.) are not attached to the genital cord by their ends in the usual way. For a backward process is given off at the point where the short branch of the sterile genital cord expands into the fertile portion of the gland; and it lies within the ventral perisome of the arm on the proximal side of the pinnule attachment. This is as fertile as the rest of the gland which is actually within the pinnule, so that the whole structure appears to be attached to the genital cord at some little distance from its end; and it comes right down into the arm at the sides of the subtentacular and cœliac canals, being attached almost directly to the genital cord (the so-called rachis), the lateral branches of which are quite short. In most sections of the arms, therefore, an ovary is to be seen on either side of the central genital cord (Pl. LXI. fig. 3).

This condition also occurs in *Metacrinus angulatus*, and in other Philippine Comatulæ, *e.g.*, *Actinometra nobilis* and *Actinometra dissimilis*;[2] and so far as one can judge from the appearance of the ventral perisome, without cutting sections, I suspect that it is tolerably common in the larger tropical Comatulæ.

Although I have examined the ovarian pinnules of a large number of species, I have never met with definite openings for the discharge of the ova; and I must therefore, like Ludwig, leave undecided the question of the origin of the relatively large openings which occur on the inner side of the pinnules of *Antedon rosacea* at the time of sexual maturity. On the other hand, I have found male individuals in which the testicular openings are evident enough (Pl. LIV. fig. 3). In *Antedon acoela* and *Antedon angusticalyx*, for example, the fertile part of the gland is short, thick, and rounded. It only extends over four or five of the pinnule segments, and is protected by the tolerably regular pavement of plates already described. At about the middle of its length one or two small conical projections rise from it towards the ventral surface of the pinnule, and

[1] *Arb. zool.-zootom. Inst. Würzburg., loc. cit.*, fig. 1, p. 261.

[2] The specific formula of this type is—$a.3.\frac{2}{3}.3.3.\frac{a}{f}$.

may be seen in an optical section of the decalcified pinnule to end in a small rounded opening. One of these openings is shown in Pl. LIV. fig. 3, and I do not think that, as a rule, there is more than one to each pinnule.

In nearly all the Crinoids which I have examined the structure of the genital gland is the same as described by Ludwig in *Antedon eschrichti*. The epithelial lining of the genital tube is continuous with that of the ovary. Individual cells of this lining enlarge at the expense of their fellows, and are gradually enclosed in follicles which are derived from the original ovarian epithelium. These follicles project freely into the lumen of the gland; but there is practically nothing which could be called an ovarian stroma.

In *Actinometra nigra*, however, there is a highly organised stroma separating the follicles; and young ova may be found in it at all stages of growth, the smallest being no larger than the nucleolus of a mature ovum. But I have been unable to make out the derivation of these germs from the epithelial cells as clearly as may be seen in *Antedon eschrichti* and similar forms.

In *Actinometra parvicirra*, on the other hand, I have failed to discover any follicular structure at all. The ova are smaller than in other types, and project slightly from the surface of a dense brown stroma in which no organised structure can be made out (fig. 4 on p. 113; Pl. LXI. figs. 3, 4). The genital cord of both these species (Pl. LXI. figs. 5, 6) is very different from that of the other Crinoids, varying greatly in shape and appearance. But the description and illustration of its peculiarities must be deferred to another occasion.

In two other multiradiate species of *Actinometra* from the Philippine Islands, however, *Actinometra dissimilis* and *Actinometra nobilis*, the genital cord of the arms is much less complex, and closely resembles that of *Antedon eschrichti*, except that it frequently contains a quantity of ill defined pigment masses. The ovaries have the same structure as those of *Antedon eschrichti* and *Antedon rosacea;* and the ova which they contain, exhibit exactly the same relation between yolk and yolk-sac as have been described by Ludwig in the ova of the latter type.[1] The whole ovum appears to be surrounded with a network formed of dark threads and clear meshes. The latter, however, are larger, and the former smaller and more delicate than in the ova of *Antedon rosacea*, as described by Ludwig.

F. The Nervous System.

That portion of the organisation of a Crinoid which corresponds to the ambulacral nervous system of other Echinoderms is of a somewhat limited character. So far as is yet known, it is confined to the ciliated floor of the food-grooves and to its minute lateral extensions in the direction of the tentacles. "Andere Zweige als die schon

[1] Die Bildung der Eihülle bei Antedon rosacea, *Zool. Anzeiger*, Jahrg. iii., 1880, pp. 470, 471.

erwähnten zu den Tentakeln sah ich nirgends von dem Nervenstamm des Arms oder der Pinnula abtreten."[1] Thus speaks Ludwig, who has given us a careful description of the ambulacral nerves of *Antedon eschrichti*, the type in which they are more completely differentiated from the ectoderm than in any other Crinoid.

Immediately beneath the closely packed ciliated epithelium which lines the food-groove is the band of nerve-fibrils, which thins away somewhat in the middle line above the radial blood-vessel. It is covered by a very delicate sheet of connective tissue on which the epithelial layer rests, and it is traversed vertically by delicate threads of a similar nature which break up the whole nerve-band into bundles of fibrils with numerous minute cells intercalated among them (Pl. LX. figs. 4, 6, *n*). Ludwig was unable to find this connective tissue sheet in *Antedon rosacea*, and I have not met with it in any other Crinoid but *Antedon eschrichti*. All the other types that I have examined have a much less defined nerve-band than this species (Pl. VIIIa. figs. 4, 5; Pl. LVII. figs. 3, 4; Pl. LIX. figs. 1, 5; Pl. LX. figs. 1, 2—*n*); and the vertical fibres which cross it are continuous with the extended lower ends of some of the epithelial cells in the layer above. In fact, both Ludwig and myself have observed this absence of a basement membrane and the connection of the epithelium with the vertical fibres in some individuals of *Antedon eschrichti*, other sections of which present the appearance described above.

Judging from Hamann's observations on the Asterids and Holothurians,[2] and also from those of Koehler[3] on the Urchins, we may consider it certain that among these "Stutzzellen" there are likewise sense-cells or neuro-epithelial cells, the inferior ends of which are connected with nerve-fibrils.

Not having worked with sufficiently well preserved material, I have never seen them, and they escaped the notice of Ludwig both in Asterids and in Crinoids; but I have no doubt whatever as to their presence.

As regards the cellular elements of the Echinoderm nervous system, it is becoming gradually recognised that nerve-cells of the usual well defined type are either altogether absent, or confined to certain specially sensitive parts of the body. Neither Hamann nor Senon have found anything but bipolar cells in the nervous system of Holothurians. Similar cells have been described and figured by Koehler in the Urchins; while, according to Romanes and Ewart[4] the cell protoplasm "is generally seen to project in two, or sometimes in three directions." The radial nerves of the Asterids, according to Hamann, contain numerous fusiform or bipolar cells, among which are a few with more than two processes; while larger cells, both bipolar and multipolar, occur in the neighbourhood of the terminal tentacle. Considering the reduced condition of the ambulacral nerve in the

[1] Crinoideen, *loc. cit.*, p. 264.

[2] Beiträge zur Histologie der Echinodermen, Mitth. I., II., *Zeitschr. f. wiss. Zool.*, Bd. xxxix. pp. 146, 309.

[3] *Op. cit.*, pp. 50–54, pl. vi. fig. 47.

[4] Observations on the Locomotor System of Echinodermata, *Phil. Trans.*, 1881, p. 836.

Crinoids, one is not surprised to find Ludwig limiting himself to the following statement—"Die winzigen Zellen, die sich zwischen den Nervenfasern finden, sind vielleicht auch nur die Kerne von Zellen, die in den Verlauf der Fasern eingeschaltet sind;"[1] and my own observations have not enabled me to add anything to this suggestion.

Hamann's observations on the Asterids have led him to discover that the so-called ambulacral nerves are only specially developed parts of a general subepithelial plexus containing ganglion-cells. This surrounds the whole body, and is traversed, though very sparingly, by vertical fibres extending downwards from some of the "Stutzzellen"; while sense-cells are intercalated among these at the bases of the respiratory cæca and elsewhere. Hamann has found a similar ectodermic plexus, distinct from the radial nerve, in Holothurians; and the presence of a corresponding structure in Cœlenterates, Nemertines, Turbellarians, Chætognatha, &c., is now thoroughly established. Thus, then, there would seem to be no reasonable doubt respecting the existence of an ectodermic nerve-plexus in the Crinoids. But even if the existence of this plexus be admitted, it is difficult to suppose that the nervous system of a Crinoid with its innumerable pairs of muscular bundles is limited to the subepithelial band in the floor of the food-grooves, its tentacular branches, and the as yet undemonstrated plexus. Leaving the latter out of consideration for the moment, Where, I would ask, are the nerves of the pinnules of *Antedon acoela* and *Antedon angusticalyx* which are shown in Pl. LIV. figs. 1–3, 5? Where is the nervous system of the large number of arms on the two posterior rays of the gigantic *Actinometra magnifica* represented on Pl. LVI. fig. 7, or that of the numerous ungrooved arms on the three other rays?

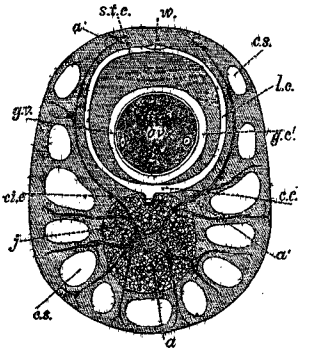


FIG. 4.—Diagrammatic transverse section of an ungrooved ovarian pinnule of *Actinometra parvicirra*, × 50. *a*, axial cord; *a'*, the branches proceeding from it; *c.c.*, cœliac canal; *ci.c*, ciliated cup; *c.s.*, connective tissue spaces in the perisome; *g.c'.*, genital canal; *g.v.*, genital vessel; *j*, skeleton of the pinnule-joint; *l.c.*, lateral canal connecting the cœliac and subtentacular canals; *ov*, ovary; *s.t.c.*, subtentacular canal; *w*, radial water-vessel.

It is difficult to conceive that these ungrooved arms and pinnules (Pl. LXI. fig. 3), which form so large a part of the entire organisation of this animal, are entirely unprovided with a nervous system, and yet the ambulacral nerve is altogether absent (fig. 4). Even when this is present, Ludwig himself admits that he has seen no other branches proceeding from it than those which supply the tentacles.

Now the muscular system of a Crinoid is unusually well developed. From the first radials to the ends of the arms every two joints are united by a pair of muscular bundles (Pl. LXI. figs. 4, 5), except in the case of the syzygies and the rare ligamentous articulations. The pinnules are always united to the arms by muscles, and in many forms there are muscles between several pairs of the pinnule-joints (fig. 6 on p. 121, *m*).

[1] Crinoideen, *loc. cit.*, p. 264.

Some species have as many as two hundred arms, each consisting of from one hundred and twenty to two hundred joints; while I have counted three hundred joints in the arms of a large *Antedon eschrichti*. The regular and graceful mode in which a ten-armed Crinoid swims is well known. The simultaneous flexions of the five right and of the five left arms alternately involve the co-ordinated contraction of several hundred pairs of well defined muscular bundles, and yet these are performed in entire independence of the ambulacral nervous system, with which the muscles are in no direct connection. In fact the eviscerated skeleton which has lost its disk and oral nerve-ring will swim as well as the entire animal. Whence does it get this power?

According to R. Hertwig[1] "Zunächst ist für mich die schon oben vertheidigte Grundanschauung maasgebend dass die Lebenserscheinungen der Ctenophoren nicht gut ohne die Annahme eines mesodermalen Nervensystems verständlich sein möchten. Seitdem durch die neueren Untersuchungen mit sicherheit Nerven bei den Medusen und Actinien nachgewiesen worden sind, ist kein Fall im Thierreich bekannt, in welchem complicirtere und raschere Muskelbewegungen ohne gleichzeitige Anwesenheit von Nerven zu Stände kämen. Sollten die Ctenophoren in dieser Hinsicht eine Ausnahme machen?"

Substitute for "Ctenophoren" the name "Crinoideen" in the above quotation, and the question arises, Where is the co-ordinating centre of the muscular movements of a Crinoid?

A centre of this kind, if it exists in such a highly organised type as a Crinoid, cannot but be regarded as belonging to a nervous system; whereas a denial of its existence brings us face to face with a physiological problem of much complexity. As a matter of fact, however, there is both physiological and anatomical evidence for the existence of such a centre, though the morphological difficulties which its presence involves are of the most perplexing character.

The well-known experiments of Dr. Carpenter[2] have shown conclusively that the fibrillar envelope of the chambered organ is the governing centre on which all the muscular movements of the animal depend, and that the movements of each individual arm depend upon the integrity of the axial cord of that arm. For they stop directly it is injured, just in the same way as injury to the chambered organ causes all the arms to be rigidly stretched out by the action of the dorsal elastic ligaments. The fibrillar envelope of the chambered organ, therefore, is the centre of a nervous system, the peripheral portion of which consists of the axial cords of the rays, arms, and pinnules, and of the numerous branches proceeding from these cords.

The occurrence of this fibrillar tissue in the stem and cirri (Pl. XXIV. figs. 1–5, *ca.*), and also in the ventral perisome, whether bare or plated (Pl. LIX. figs. 2–4, 6, 7;

[1] Ueber den Bau der Ctenophoren, *Jenaische Zeitschr.*, Bd. xiv. p. 437.

[2] *Proc. Roy. Soc. Lond.*, 1876, p. 453.

Pl. LX. fig. 2—*a.d.*; fig. 6, *a'*. Figs. 4, 5, 7, *a'*; fig. 8, *a.d.*), where muscle fibres are absent, indicates that if it be nervous, it must be not only of a motor but also of a sensory nature. This conclusion also follows from the fact that stimulation of one of the oral pinnules of *Antedon rosacea* causes the flexion of all the ten arms. This result is not simply due to general irritability; for if so, it would follow when any pinnule was stimulated; whereas stimulation of one of the ordinary pinnules is only followed by flexion of the arm which bears it. This experiment therefore is evidence of a reflex action of a somewhat complex nature; and the axial cords must be the paths of both afferent and efferent impulses. For there is no ambulacral nerve in these oral pinnules, which resemble those on the hinder arms of *Actinometra* (Pl. LVI. fig. 7; Pl. LXI. fig. 3) in being ungrooved, and devoid of tentacles, blood-vessels, and ventral nerve (fig. 4). The latter is normally connected with the tentacles, and possibly also with a general subepidermic plexus; but it has nothing whatever to do with the bodily movements of the animal, though perhaps influencing those of the tentacles and of the marginal leaflets or covering plates.

Here then we have evidence in the Crinoid of a mesodermic nervous system analogous to that which has been discovered of late years in the Cœlenterates, Worms, and Chætognatha. As regards the latter group, O. Hertwig is inclined to think that "bei den Chætognathen sensibles und motorisches Nervensystem von einander vollständig gesondert sein, ersteres wäre ektodermal, letzteres gleich den Muskeln mesodermal."[1]

Considering that nervous tissues are well developed in the mesoderm of Cœlenterates, one would certainly expect to find them in that of Echinoderms. The nervous system of a Holothurian only remains in connection with the epidermis at the distal ends of the tentacles and tube-feet; while the radial nerves of Ophiurids and Urchins are separated from the exterior by limestone plates, though coming into connection with the epidermis on the tube-feet. Besides the subepidermic plexus on the outside of the shell of an Urchin which sends fibrils to the muscles of the pedicellariæ, there is another which is formed by filaments that are given off from the lateral branches of the radial nerves, the connection of which with the subepidermic plexus has not been definitely traced. Romanes and Ewart have further discovered that the general co-ordination of the spines for the purpose of locomotion depends on the integrity of an internal nervous plexus which is "everywhere in intimate connection with the external, apparently through the calcareous substance of the shell."[2]

There is, therefore, no very great difficulty involved in the belief that a mesodermic nervous system is present in the Crinoids. The morphological difficulties resulting from its anti-ambulacral position are, however, considerable. But they are of precisely the same character as we have to face, when describing the chambered organ and the vascular axis of the stem as a part of the circulatory system of a Crinoid. Ludwig appears to have

[1] Die Chætognathen, *Jenaische Zeitschr.*, Bd. xiv. p. 234.
[2] *Phil. Trans.*, 1881, p. 874.

found no difficulty in this, but despite the physiological improbability of the want of innervation to the muscular bundles, he declines to accept the fibrillar envelope of the chambered organ and its extensions into the stem and arms as belonging to the nervous system of a Crinoid. One ground for his objection lies in the presence of this fibrillar tissue in the axis of the stem and of the cirri that it bears, which contain no muscular tissue. This point, which supports Dr. Carpenter's view rather than opposing it, will be considered later.

The only explanation of the presence of this fibrillar tissue within the skeleton which Ludwig can suggest is as follows:—"Die Faserstränge sind zu betrachten als unverkalkt gebliebene Theile der bindegewebigen Grundlage der Kalkglieder, deren Aufgabe es ist, aus dem Blutgefässsystem, genauer aus den funf Kammern, die ernährende Flussigkeit aufzunehmen und den Arm- und Pinnulagliedern zuzuführen."[1]

I have no doubt whatever that the axial cords are permeated by a nutritive fluid, which finds its way from the chambered organ into the substance of the organic basis of the skeleton. For I have frequently found coagulum, both in this last and in the axial cords themselves; but I should hesitate to speak of either of these as connective tissue. The closely set fibrils forming the axial cords are quite distinct from the nuclear network which interpenetrated the calcareous substance; and both are as different as possible from the connective tissue fibres of the articular ligaments, or the general connective tissue of the ventral perisome (see fig. 6 on p. 121). Simroth has given an excellent description and figures of the nucleated reticulum forming the organic basis of the skeleton in Ophiurids,[2] and nearly everything which he says is equally applicable to the Crinoids. The nature of this nuclear tissue is well shown in Pl. Vb. fig. 1, Pl. XXIV., and Pl. LVIII. figs. 2, 3; and its distinctness from the close fibrillar structure of the stem-axis is very apparent. The general aspect of the axial cords in thin sections is identical with that of the Ophiurid nerves as represented by Simroth, who finds the nerve-fibrils to be connected with bipolar cells. Fig. 32 on his pl. xxxiv., which shows the relation of the radial nerve to the organic substance of the under arm-plates beneath it, would serve, with very little alteration, for a part of a longitudinal section of the arm or pinnule of a Crinoid. The fibrillation of the axial cords and their marked differences from the organic basis of the skeletal plates is well seen in sections through the calyx of the Pentacrinoid. At this early stage the cords lie on the ventral surface of the flat calyx plates outside the organic basis of the skeleton altogether; and it is by an endogenous thickening of the calcareous substance of these plates that the cords come to lie in grooves which are subsequently closed into canals; while by a further continuance of the same process these canals are eventually so surrounded by calcareous tissue that they come to occupy the centre of the successive joints of the skeleton.

Ludwig's view of the nature of the axial cords is therefore not altogether in accordance

[1] Crinoideen, *loc. cit.*, p. 340. [2] *Op. cit.*, pp. 433, 434.

with what we know of their origin; and it likewise fails to account for their relations in the adult Crinoid. If this fibrillar tissue were limited to the skeleton, there might be some reason in Ludwig's suggestion. But it gives no rational explanation whatever for the extension of branches from the axial cords of the skeleton through the perisome of the disk and arms, up to the bases of the tentacles at the sides of the food-groove (Figs. 4–7, *a'*. Fig. 8; Pl. LIX. figs. 2–4, 6, 7; Pl. LX. fig. 2—*ad*; Pl. LX. fig. 6, *a'*), and even as asserted by Perrier, into the tactile hairs borne by these tentacles.[1]

Ludwig's theory too entirely fails to account for the elaborate arrangement of commissures which one finds in *Comatula* and *Pentacrinus* (Pl. XXIV. figs. 7–9; Pl. LVIII. figs. 1–3), and in a less degree in *Bathycrinus* (Pl. VIIb. fig. 4, *cco*), *Rhizocrinus* (Pl. VIIIa. fig. 6, *cco*, *ico*), and *Encrinus*. Why should the first radials and the axillaries be in such special need of nutrition that the former should possess both interradial and intraradial commissures, and the latter no less than four cords, to say nothing of the transverse commissure? Five radial cords starting directly from the envelope of the chambered organ would surely serve all the necessary purposes of nutrition. As it is, however, each ray and indeed each arm is supplied by fibres from two of the primary interradial trunks. This complex arrangement receives no explanation whatever on Ludwig's theory, though it is easily understood if we suppose that the axial cords are the means by which co-ordinated impulses reach the muscles from a governing centre.

Their anatomical structure also favours this view. In a paper which was published some years before the discovery of ambulacral nerves in the Crinoids, Baudelot quoted Müller's description of the so-called arm-nerve (*i.e.*, the genital cord), and apparently adopted it as correct.[2] But he also stated that he could not help being struck with the resemblance "qui existe entre la structure du cordon fibreux central des bras et la cordon nerveux des autres Échinodermes." He described its relations pretty accurately, and then proceeded to say "Ainsi donc chez les Comatules il existe des parties qui evidemment n'appartiennent point au système nerveux, et qui dans leur disposition aussi bien que leur structure offrent une analogie presque complète avec les cordons nerveux des autres Échinodermes."

I do not know what reason Baudelot may have had for his conviction that the axial cords are evidently not of a nervous nature, unless he had implicitly accepted Müller's account of the nervous system of a Crinoid. A very little trouble, however, would have convinced him that this was totally incorrect. In fact Dr. Carpenter had referred to Müller's error four years before the publication of Baudelot's observations, and had also mentioned that he had reasons for regarding the branching fibres proceeding from the axial cords to the muscles as probably having the function of nerves. Had Baudelot

[1] *Comptus rendus*, t. xcvii. p. 188.

[2] Contribution à l'histoire du système nerveux des Échinodermes, *Archives d. Zool. expér.*, t. i. p. 211.

been acquainted with these facts, the non-nervous nature of the axial cords would probably have been somewhat less "evident" to him.

According to Ludwig the axial cords consist of "feinen Fasern, zwischen welchen man, namentlich an der Peripherie der ganzen Masse, Zellen oder doch zellenähnliche Gebilde (Zellkerne ?) findet."[1] As a matter of fact I can find no difference between the appearance of the fibrils forming the axial cords and those of the ambulacral nerve, either in transverse or in longitudinal section; and I wonder that Ludwig was not struck by the resemblance of the two, especially in *Antedon eschrichti*, in some specimens of which, at any rate, it is very marked. There are the same delicate fibrils with intercalated cells as in the ambulacral nerve, and in some individuals the two have exactly the same appearance in cross-section; though the axial cords more usually are somewhat of a yellowish tinge, which renders it easy to recognise their branches that extend outwards from the skeleton into the connective tissue of the general perisome (figs. 4–8; Pl. VIIb. figs. 6, 7; Pl. LIX. figs. 2–4, 6, 7; Pl. LX. figs. 2, 6).

Dr. Carpenter's theory of the nervous nature of the axial cords of the arm was originally suggested by his discovery that they give off branches which extend over the ends of the muscular bundles. This is well seen in moderately thick transverse sections of an arm which are viewed as opaque objects. But the study of thin transparent sections shows that these branches to the muscles are only portions of a largely developed network which originates in the axial cords and extends both to the dorsal and to the ventral surface of the arm or pinnule. Ludwig states that he had been unable to convince himself of the existence of the muscular branches described by Dr. Carpenter. This may well have been the case in the small arms of *Antedon rosacea;* though I have had no difficulty in finding them in this species, and Perrier has been equally successful. But I cannot comprehend his not having seen some of these lateral extensions of the axial cords in the arms and pinnules of *Antedon eschrichti.* They are not limited to the skeleton, for I have hardly a section that does not show a part of one or other of the two main trunks which extend up into the ventral perisome at the sides of the food-groove, as represented in Pl. LX. fig. 6, *a'*. Pinnule sections too may be obtained without difficulty, in which the whole course of one of these branches may be seen from its origin in the axial cord right up into the substance of one of the respiratory leaflets bordering the food-groove. In Ludwig's figures of sections through the arms and pinnules, however, the axial cord is represented as a mere dark circle without any trace of lateral extensions.

The doctrine of the nervous nature of these cords has recently received support from a quarter in which it was formerly denied; for Prof. Perrier has reinvestigated the subject and has brought forward additional evidence of much value. He has seen the branches of the axial cords in *Antedon rosacea*, and states, like Baudelot and Teuscher,

[1] Crinoideen, *loc. cit.*, p. 316.

that they have all the appearance of being true nerves.[1] He further describes how their ultimate subdivisions "aboutissent à des cellules étoilées, dont chacune se prolonge en un fibre musculaire. Des ramifications de ce genre sont également en rapport avec les fibres que contiennent les tentacules ambulacraires et dont un grande nombre se tiennent dans les papilles sensitives de ces tentacules que Ludwig considère à tort comme creuses." Elsewhere he states that the cords are invested with a sheath of stellate cells which are themselves related to connective-tissue corpuscles, and through these with the ectodermal cells of the arm. These statements of Perrier's are of considerable importance, and should his observations be confirmed the nervous nature of the axial cords will, I think, be at last admitted, even by those whose scheme of Echinoderm morphology is founded upon the archetype of a Stellerid or Urchin. These, however, are formed almost entirely upon the left larval antimer, whereas the chambered organ of a Crinoid and its downward extension into the stem are formed in the right peritoneal tube. (See Appendix, Note G.)

The branches from the axial cords of the rays and arms, to which allusion has so frequently been made, vary considerably in their development and distribution. Among all the numerous Crinoids, stalked and free, that I have examined, *Rhizocrinus* is the only one in which these branches have not been visible. I see no reason to doubt their existence, however; but the genus is one of small size, and is also permanently fixed through life, so that one would not expect to find large muscular branches proceeding from the axial cords, as in the Comatulæ and Pentacrinidæ which are free or semi-free, and can use their arms for the purpose of swimming; whereas, according to Agassiz,[2] the movements of extension and flexion of *Rhizocrinus* are but slow and gradual. The branches are also poorly developed in the massive and sessile *Holopus*. But in *Bathycrinus*, in the Pentacrinidæ, and in the Comatulæ they are very largely developed, occurring not only in the arms and rays but also in the stem and cirri. They vary considerably in their extent, some portions of the stem showing them abundantly(Pl. XXIV. fig. 2, *ca'*), while in others they are less numerous. An optical section of two decalcified stem-joints of *Bathycrinus aldrichianus* is shown in Pl. VIIa. fig. 1. The larger branches of the axial cord (*ca'*) are seen with a low power where the radial spaces render the stem-substance more transparent than elsewhere, but this gives no idea of the minuteness and complexity of their subdivision, which only reveals itself by the use of a high power.

In *Pentacrinus wyville-thomsoni* again I have found these branches to be abundantly developed in some stem-joints and almost entirely absent in others (Pl. XXIV. figs. 1–5). The fibrillar envelope surrounding the vascular axis is sometimes in immediate contact with the reticular tissue which forms the organic basis of the skeleton (figs. 2, 3). But in other joints it is closely surrounded by a layer of large pigment bodies like those which occur scattered in more or less abundance through the skeletal tissue (fig. 5, *p*). In other sections again, fibrillar extensions of the central axis pass outwards from it

[1] *Comptes rendus*, t. xcvii. p. 188.

[2] *Ill. Cat. Mus. Comp. Zoöl.*, No. viii. p. 29.

between the surrounding pigment bodies, and ramify in the small spaces left between the petaloid areas that are occupied by the five interradial ligaments (Pl. XXIV. fig. 1; fig. 2, *ca'*). These extensions towards the surface of the stem eventually become so fine that I have been unable to trace them in the somewhat thick sections with which I have been obliged to content myself, owing to the large size and the toughness of the stem ligaments. But from what I have seen in the arms, and more especially in the pinnules, I have very little doubt that the ultimate subdivisions of these branches are in connection with a subepidermic plexus. I have found similar branches in the cirri.

The occurrence of this tissue around the axial vessels of the stem and cirri has been employed by Ludwig as an argument against its nervous nature on account of the absence of muscles in these organs.[1] "Wozu also ein dieselben in ihrer ganzen Länge durchziehender (motorischer) Nervenstrang?" The same argument might be employed with respect to the extension of branches from the axial cords within the calyx up into the anambulacral plates on the sides and ventral surface of the disk of *Pentacrinus decorus* (Pl. LIX. figs. 2–4, *ad*). But their presence is readily understood if we consider them as sensory nerves establishing a communication between an ectodermic plexus and the axial cords of the rays, which all commence in the envelope of the chambered organ situated within the calyx. It is however in the arms and pinnules that the lateral extensions of the axial cords are most evident (Pl. LXI. fig. 6), and the inadequacy of Ludwig's theory as to their nature is strikingly manifest.

The species in which I have found these branches best developed are *Bathycrinus aldrichianus*, *Pentacrinus decorus*, *Antedon eschrichti*, *Actinometra parvicirra*, and *Actinometra nigra*. But they may also be met with in less abundance in the small arms and pinnules of *Antedon rosacea*, and I cannot understand how they escaped the notice of Greeff, Teuscher, and Ludwig.

The lateral branches from the central fibrillar axis in the stem of *Bathycrinus aldrichianus* have been already mentioned (Pl. VIIa. fig. 1, *ca'*). The axial cords within the rays and arms have a similar extensive distribution. Numerous branches proceed outwards from them into the calcareous substance of the successive joints, as is shown in the second and axilliary radials, which form an important part of the cup enclosing the visceral mass (Pl. VIIb. figs. 6, 7, *a'*). The arms become free higher up, however, and the deep median groove in the ventral surface of the skeleton receives the ambulacrum with its armature of covering plates (Pl. VII. fig. 8). The axial cord gives off a large branch on each side which proceeds upwards, subdividing freely as it goes. The ultimate branches, many of which have bipolar cells intercalated in their course, extend right up to near the top of the side-walls of the arm-groove, where they become so small that I have been unable to trace them further (Pl. VIIIa. figs. 4, 5, *a'*). I have occasionally seen a cell with three processes instead of two, but these are rare. The ambulacral nerve

[1] Crinoideen, *loc. cit.*, p. 335.

varies considerably in appearance, being relatively thick in some parts and almost totally absent in others; for I have never found it to extend right across the food-groove as it does in other species (Pl. VIIIa. figs. 4, 5, *n*).

I have cut sections of the arms and pinnules of some half dozen species of *Actinometra* and have found abundant extensions from their axial cords in all cases. The fibrillar tissue generally has a strong yellowish tinge, which renders it easy to follow when it leaves the substance of the skeleton and enters the ventral perisome. *Actinometra parvicirra* and *Actinometra nigra*, both from the Philippines, have, however, given me the best results. The axial cord enlarges slightly in the centre of each joint of the ray, arm, or pinnule,

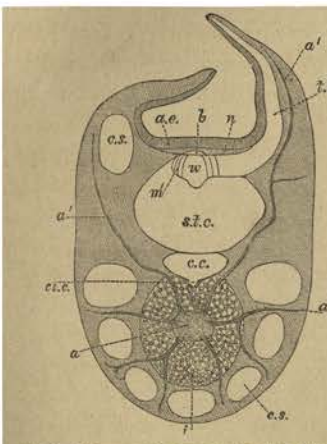


FIG. 5.—Diagrammatic transverse section through the end of a grooved pinnule of *Actinometra parvicirra*, × 70. *a*, axial cord; *a'*, the branches proceeding from it; *a.e.*, ambulacral epithelium; *b*, radial blood-vessel; *c.c.*, coeliac canal; *ci.c.*, ciliated cup; *c.s.*, connective tissue spaces in the perisome; *j*, skeleton of the pinnule-joint; *m'*, transverse muscle-threads in the water-vessel; *n*, radial trunk of the ambulacral nervous system; *s.l.c.*, subtentacular canal; *w*, radial water-vessel; *t.b.*, its tentacular branch.

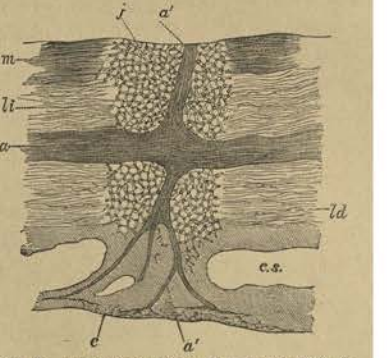


FIG. 6.—Longitudinal section of a pinnule-joint of *Actinometra nigra*, × 50. *a*, axial cord; *a'*, the branches proceeding from it; *c.s.*, connective tissue spaces in the perisome; *e*, epidermis; *j*, skeleton of the pinnule-joint; *ld*, dorsal ligament; *li*, interarticular ligament; *m*, muscle.

and gives off four branches, or occasionally more (Pl. LXI. fig. 6; woodcuts, figs. 4, 5) One pair of these runs towards the dorsal surface, and breaks up into successive subdivisions, the last of which are exceedingly fine and can be traced no further (woodcut, fig. 6, *a'*). The other pair extends towards the ventral side of the skeleton, and passes out of it into the perisome at the sides of the genital glands, where they are continued upwards towards the ventral surface of the arm or pinnule, which may or may not bear a food-groove, according to the part of the body from which it comes.

In both these species the perisome contains a number of more or less regularly arranged spaces in the connective tissue (woodcuts, figs. 4–7, *c.s.*), and the branches of the

axial cords run in the partitions between them. These branches have no regular mode of subdivision, no two pinnules being exactly alike; while they are not symmetrical on the two sides of the same pinnule. Longitudinal sections of the pinnules of *Actinometra nigra*[1] show that these branches which come up to the ventral side in successive segments of the pinnules (woodcuts, figs. 4–7, *a'*) are united by continuous trunks that run along the upper surface of the pinnule right and left of the ambulacrum (woodcut, fig. 7, *lt*); they send branches upwards between the connective tissue spaces, of the same kind as those which appear in transverse section.[2] The nervous structures in these pinnules thus consist of four principal trunks, three of which are intimately united by a network of fibrils, while the fourth and smallest is the ambulacral nerve. This is not yet known to be connected with any other structures, though I strongly suspect that it is continuous at the sides of the food-groove with a subepidermic plexus covering the pinnule and communicating with the numerous branches of the axial cord.

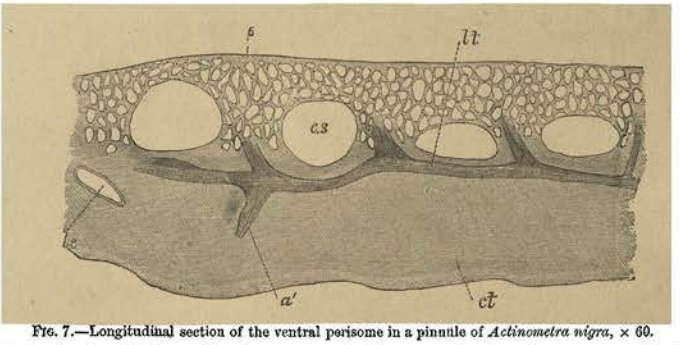


FIG. 7.—Longitudinal section of the ventral perisome in a pinnule of *Actinometra nigra*, × 60.

a', Ventral ascending branch of the axial cord; *c.s*, connective tissue spaces in the perisome; *ct*, connective tissue above the ovary; *e*, epidermis; *lc*, lateral canal, connecting the cœliac and subtentacular canals; *lt*, one of the lateral trunks which connects the ascending branches of the axial cord (*a'*).

N.B.—This section passes to one side of the medio-ventral line of the pinnule.

Sections of the arms and pinnules of *Antedon eschrichti* give much the same results. The ventral branches of the axial cords in the arms extend upwards along the sides of the cœliac canal, curve round the outer walls of the subtentacular canal, and pass on into the elevated folds of tissue bounding the food-groove, as shown in Pl. LX. fig. 6, *a'*. They do not seem to subdivide so freely as in the tropical *Actinometra*, but in both genera I have traced their smaller fibrils into the little respiratory leaflets along the edges of the food-groove. Perrier has seen the same thing in *Antedon rosacea*, and believes

[1] Théel's figure of a dorsal nerve-trunk in *Elpidia glacialis* with its muscular branches (*K. Svensk. Vetensk. Akad. Handl.*, Bd. 14, No. 8, Taf. iv. fig. 18) has a wonderful resemblance to a longitudinal section of the axial cord in a Crinoid pinnule.

[2] Woodcuts figs. 4 and 5 are composite figures made up from the study of some half dozen sections through the central part of a pinnule-joint and the overlying ventral perisome. Woodcuts figs. 6 and 7, however, are diagrammatic representations of single sections, and I have plenty more of the same character.

himself to have traced the connection of the ultimate fibrils with those in the tactile papillæ of the tentacles.[1]

The discovery of this extensive perisomic or parambulacral network, derived from the axial cords of the arms and pinnules in various species both of *Antedon* and of *Actinometra*, led me to suspect its presence at the sides of the disk-ambulacra; and after several unsuccessful attempts, chiefly due to the poor state of preservation of my material, I met with one disk of *Antedon eschrichti* which yielded the most satisfactory results. Portions of two sections are shown in Pl. LIX. figs. 6 and 7; while woodcut fig. 8 embodies the result of my studies of a few successive sections in the same series.

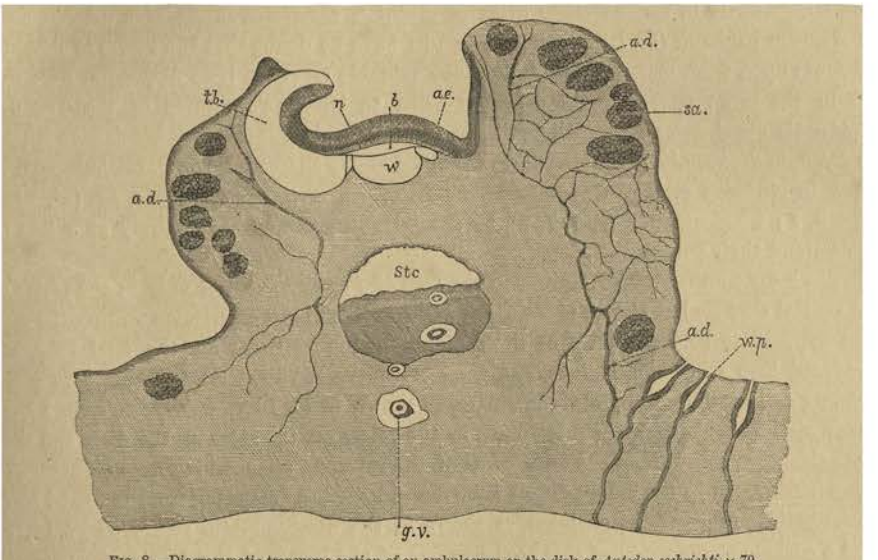


FIG. 8.—Diagrammatic transverse section of an ambulacrum on the disk of *Antedon eschrichti*, × 70.

a.d., The parambulacral nervous network—this is filled in from a few successive sections, only isolated portions of it being visible in any single one; *a.e.*, ambulacral epithelium; *b*, radial blood-vessel; *g.v.*, genital vessel; *n*, radial or ambulacral nerve, the subepithelial band; *sa.*, sacculi; *Stc*, subtentacular canal; *t.b.*, tentacular branch of *w*, the radial water-vessel; *w.p.*, water-pores.

There appears to be a good deal of individual variation; but in this one species, at any rate, the elevated folds of perisome which bear the ambulacra contain a wonderfully rich network of delicate fibrils of precisely the same nature as those which occur at the sides of the brachial ambulacra (Pl. LX. fig. 6, *a'*); and the brachial plexus may be followed down on to the disk at the sides of the food-groove (woodcut, fig. 8, *a.d.*). I have very little doubt that it is joined by branches which proceed upwards into the ventral perisome from the axial cords within the radials and lower brachials. But as

[1] *Comptes rendus*, t. xcvii. p. 188.

I have never cut through an entire *Antedon eschrichti*, I am unable to say positively that this is the case, though it certainly is so in *Pentacrinus decorus*.

This parambulacral network extends right down along the food-grooves, being especially developed among the sacculi (woodcut, fig. 8, *a.d.*); and it forms an annular plexus in the connective tissue of the lip, but of course farther from the mouth than the ambulacral nerve-ring. Bipolar, and occasionally multipolar cells are in connection with its finer fibrils, which can be followed very close to the superficial epithelium. Hardly any traces of it are visible in the interpalmar areas between the ambulacra, which are chiefly occupied by the water-pores, though it is extensive enough at their sides. I have seen it more or less satisfactorily in various other disks of *Antedon eschrichti*, in *Antedon rosacea*, and in *Antedon carinata* (Pl. LX. fig. 2, *ad*); and I have no doubt that the action of suitable reagents upon fresh material would give very valuable results. [See Appendix, Note G.]

In the mean time I would draw attention to Hamann's figures of the "zu der Epidermis abgehenden Nervenzüge, die man kurzweg als Hautnerven bezeichnen kann" in *Synapta digitata*.[1] If the structures described above as forming the parambulacral network in *Antedon eschrichti*, *Actinometra parvicirra*, *Actinometra nigra*, &c. (Pl. LIX. figs. 6, 7; woodcuts, figs. 4, 5, 7, 8), be not "Hautnerven," I am entirely at a loss to understand their nature.

The same fibrillar threads appear in the disk of *Pentacrinus*, not only in the plates of its ventral surface, but also in those which are developed on the perisome uniting the rays and support it below. Many of these plates, including those on the anal tube, are produced into small blunt spines, and these "Hautnerven" extend from plate to plate, sending delicate fibrils up into the spines, as shown in Pl. LIX. figs. 2–4, *ad*. I have many sections which contain these fibres in the plates on the sides of the disk, and they are evidently derived from the axial cords of the rays and arms, which give off numerous branches. Even in the basal plates I have found branches extending from the axial cords towards the surface of the skeleton, as shown in the diagrammatic figure on Pl. LXII.; and a curious modification of this occurs in one of the basals of the *Pentacrinus wyville-thomsoni* which was devoted to anatomical research. The two secondary cords (Pl. XXIV. fig. 7, *ar*) which result from the bifurcation of the primary interradial trunk (*ai*) and eventually enter different radials, are united to one another within the substance of the basal plate by a commissure. This reminds one at once of the horizontal commissure discovered by Ludwig in the radial axillary, by which the individual cords of the two arms borne by the axillary are united immediately beyond their point of separation.

The arrangement of the axial cords within the radials of *Pentacrinus* or *Metacrinus* is exactly the same as in the Comatulæ. The primary trunks which proceed from the angles of the chambered organ (Pl. XXIV. fig. 7; Pl. LVIII. figs. 1, 3, *ai*) fork within the basals; and the two secondary cords which result from the bifurcation pass out from

[1] *Op. cit.*, *Zeitschr. f. wiss. Zool.*, Bd. xxxix. p. 322, Taf. xxii. figs. 43–45.

the basals and enter two adjacent radials (Pl. XXIV. figs. 7–9; Pl. LVIII. figs. 2, 3, *ar*) There are thus two apertures on the upper surface of each basal, and two on the under surface of each radial (Pl. XII. figs. 11, 14, 22, 25; Pl. XVIII. figs. 5, 7; Pl. XX. figs. 2, 3, 6, 9; Pl. XXI. figs. 6*a*, 6*b*, 6*c*, 7*a*, 7*b*; Pl. XXX. fig. 5, 7, 8; Pl. L. fig. 5). As the two cords which enter each radial converge towards its distal surface, each of them is joined laterally by a commissure to its fellow in the next radial which springs from the same primary trunk as itself. These lateral branches form the interradial, and by far the larger portions of a circular commissure which unites the five pairs of cords within the radials (Pl. XXIV. fig. 9, *c.co*; Pl. LXII.); while the two converging cords within the substance of each radial are also united by a very short intraradial commissure (Pl. XXIV. fig. 9, *i.co*).

This circular commissure occupies a canal which traverses the radials from side to side, lying in the Comatulæ very close to their distal face, but more centrally in the Pentacrinidæ. Its openings on the lateral faces of the radials are shown in Pl. XII. figs. 11, 22; Pl. XX. fig. 6; Pl. XXI. figs. 6*a*, 6*b*, 6*c*; Pl. XXX. figs. 5, 8.

The two secondary cords within the basals and the proximal parts of the radials of *Pentacrinus* are more widely separated than the corresponding structures in the Comatulæ (Pl. XXIV. figs. 7, 9; Pl. LVIII. figs. 1, 2—*ar*), so that the intraradial commissure is better defined (Pl. XXIV. fig. 9, *i.co*). Beyond the circular commissure the two axial cords of each ray lie very close together, though still distinct, just as in the Comatulæ. Each of them forks in the axillary, and there is the same horizontal commissure as was described by Ludwig in *Antedon rosacea*.

So far as the fossil Neocrinoids are concerned, *Encrinus* and *Apiocrinus* seem to have had an arrangement of the axial cords essentially similar to that prevailing in the Pentacrinidæ and Comatulæ. In the former genus, as already pointed out by Ludwig, no canals have been described either for the intraradial commissure or for the horizontal commissure in the axillary; while the secondary radial cords remain distinct as far as the axillaries, even to the extent of being lodged within separate canals in the second as well as in the first radials. The double canals are continued through the whole length of the arms; and in some species these consist, after the base, of a double row of joints, each of which is pierced at its inner end by the two canals. The absence of any canals which could lodge an intraradial commissure is very singular; and it is also remarkable that the interradial portions of the circular canal should lie so completely in the distal parts of the radials. They only join the axial canals where these open on the distal faces of the radials; so that if an intraradial commissure were present at all, it must have lain just at the edge of the first radials, almost among the ligamentous bundles uniting them to the following joints.

The axial cords of *Encrinus* were lodged in canals throughout their whole length, those within the basals occupying grooves within the substance of the plates which were

covered and converted into canals by what Beyrich calls "an inner epiphysis."[1] This was of no great thickness, and was therefore easily worn so as to expose the grooves beneath. In *Apiocrinus*, however, the basals were simply grooved for the reception of the bifurcating interradial cords, though the radials were pierced by canals as usual. Beyrich[2] speaks of the arrangement of the canals being the same as in *Encrinus*, and de Loriol refers to the circular canal;[3] but I have been unable to make out definitely whether any intraradial commissure were present or not. At any rate the type resembles *Pentacrinus* rather than *Encrinus*; for there is only one opening on the distal face of each radial instead of two, and in correspondence with this only a single series of arm-joints.

We know nothing respecting the distribution of the canals in the calyx of the Bourguetierinidæ, but the course of the axial cords in *Rhizocrinus* is somewhat different from that of *Apiocrinus*, and this is still more the case in *Bathycrinus*. The basals of *Rhizocrinus* are of considerable height (Pl. IX. figs. 1–3; Pl. X. figs. 2, 3; Pl. LIII. figs. 7, 8), and the primary interradial cords of greater length than usual; but they are completely enclosed in canals, and bifurcate immediately beneath the synosteal surface on which the first radials rest. The two limbs of each fork are very widely separated, turn off horizontally, and form themselves the interradial portion of the circular commissure, instead of proceeding directly onwards through the radials, as their fellows do in *Pentacrinus* (Pl. XXIV. figs. 8, 9, *ar*). The two secondary cords which enter the small radial are immediately united just within its inner face by an intraradial commissure (Pl. VIIIa. fig. 6, *c.co*), and then proceed onwards towards the single opening on the distal face (Pl. X. figs. 1–4). The above description differs in some points from that given by Ludwig, who took an entirely erroneous view with respect to the basals of this type, and failed to find the intraradial commissure. The subject is discussed more fully in the anatomical account of the genus (pp. 249–252).

A still simpler condition than that of *Rhizocrinus* is presented by the aberrant genus *Bathycrinus*. The basals are low and the radials high (Pl. VII. fig. 2; Pl. VIIIa. fig. 1), exactly the reverse of what we meet with in *Rhizocrinus* (Pl. IX. figs. 1–3; Pl. X. figs. 2, 3; Pl. LIII. figs. 7, 8). The primary interradial cords (Pl. VIIb. figs. 2, 3, *ai*) do not fork within the basals, as is usually the case; but they pass upwards between every two radials, the sides of which are grooved for their reception (Pl. VII. fig. 6*a*). At the level of about half the height of the radials the primary cords divide, and the two branches of each pass off right and left into the radials, where they form an interradial commissure, from the angles of which the axial cords of the rays proceed (Pl. VIIb. fig. 4, *c.co*); while the two converging portions of the interradial commissure within each radial are united by an intraradial commissure just as in *Rhizocrinus*. The principal difference between the two types is that the primary interradial cords of *Rhizocrinus* fork within the basals, while those of *Bathycrinus* pass upwards between the radials, and then turn off laterally within

[1] *Op. cit.*, p. 22. [2] *Op. cit.*, p. 21. [3] Paléont. Franç., *op. cit.*, p. 313.

these plates. It appears to me very probable that this may also be the case in *Thaumatocrinus* (Pl. LVI. figs. 1–4), *i.e.*, that the primary cords pass right up out of the basals into the interradials and then divide, so that the secondary cords would enter the sides of the radials as in *Bathycrinus*, instead oftheir inner ends as in *Pentacrinus* and *Comatula*.

G. The Sacculi, and the Colouring Matters.

The nature and functions of the sacculi are as much a puzzle to me now as they were when I first began to study the Crinoids in 1875; and I have nothing to add to the observations of Wyville Thomson and Perrier on their appearance in the living animal, both larval and adult. Colourless during life, they become strongly tinged after death by the pigment set free from the perisome. Their occurrence in the wall of the digestive tube in *Antedon rosacea* was first noticed by Ludwig; and I have found them in the very lowest part of the cup of a larva with five cirrus-stumps, just above the chambered organ. But this is the only species known to me which presents this peculiarity. In all other types in which the sacculi occur at all, they are invariably limited to the immediate neighbourhood of the water-vessels. Abundant in most species of *Antedon*, they never occur in *Actinometra*, and I suspect that Ludwig's reference to their presence in this genus is due to an oversight.[1] At any rate I have not been able to find them in *Actinometra trachygaster* and *Actinometra bennetti*, the two species which had come under his observation.

They vary considerably in distribution among the other genera of Comatulæ. I have not succeeded in finding them in *Thaumatocrinus*, while they are but scantily developed in the three species of *Atelecrinus*. *Eudiocrinus indivisus* and *Eudiocrinus atlanticus* have them in abundance; while there are few in *Eudiocrinus varians* and none in *Eudiocrinus semperi* or in *Eudiocrinus japonicus*, so far as I have been able to make out. *Promachocrinus kerguelensis* has them on the pinnules, but they are very scanty or absent elsewhere. Neither have I found any in a small series of sections through a *Holopus*-arm; and though structures of the same nature occur sparingly in *Pentacrinus*, *Rhizocrinus*, and *Bathycrinus*, they are but poorly developed and irregular in their occurrence.

In some species of *Actinometra* individual vesicular bodies resembling the elements of the sacculi are scattered through the ventral perisome; but there is no regular arrangement of them into groups at the sides of the ambulacra as in the endocyclic Crinoids. When the ambulacra are plated, as in many tropical *Antedons*, the sacculi are lodged between the successive side plates, the front edges of which are notched for their reception (Pl. LIV. figs. 4, 6–9); while they occupy little pits in the large plates which cover the

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxix., 1877, p. 59.

ovarian pinnules of *Antedon acoela* and *Antedon angusticalyx*, and also in the substance of the small later joints of the pinnules (Pl. LIV. fig. 5).

As regards the colouring matters in the body of a Crinoid I can do no more than refer to the important observations of Prof. Moseley, who employed the spectroscope on five different occasions when Pentacrinidæ were dredged in the Pacific (Stations 170, 192, 209, 210, 214). *Metacrinus* was obtained at all these Stations, but *Pentacrinus* only at the first and the last two.[1]

The colouring matter yielded by most of the specimens is distinguished by very well-defined absorption spectra, and has been termed "Pentacrinin" by Prof. Moseley. It is freely soluble when fresh in slightly acidified alcohol, and gives a solution which is of an intense pink when viewed by transmitted light, but acquires a bluish-green colour when rendered alkaline by the addition of ammonia. "The fresh colouring matter is soluble in fresh water, but remains partly suspended, forming a slightly opaque dark purple solution, which gives, when quite fresh, a mixed acid and alkaline spectrum." All the species, both of *Metacrinus* and *Pentacrinus*, which were obtained off the Kermadec Islands at Station 170 were of a uniform dusky colour when fresh, being evidently coloured by acid pentacrinin. The three species of *Metacrinus* dredged off the Ki Islands at Station 192 "when in the fresh condition, had their stems almost white, and their crowns of a light yellow or light reddish-orange, showing no purple coloration at all; and those dredged off the Panglao and Signijor Islands (Station 210) were almost colourless; nevertheless, when placed in alcohol, they yielded a solution which was deeply coloured of a sap green, and which when acidified, became of the usual deep pink of pentacrinin. The pentacrinin was thus in these examples, though present in great adundance, entirely masked."

I am unfortunately unable to name with certainty the species which was obtained at Station 210, no specimens having reached me with the label of this Station; though, according to Sir Wyville Thomson's MS. notes, four specimens of two species of Pentacrinidæ were obtained here. One of these was perhaps the single individual of *Metacrinus murrayi*, which reached me without any record of its locality; while the other must have been either *Pentacrinus alternicirrus* or *Pentacrinus naresianus*. Three out of seven individuals of the latter species came into my hands without any indication of locality; while a few of the fourteen specimens of *Pentacrinus alternicirrus* were in the same condition. Both were obtained at Station 214, off the Meangis Islands.

There is, however, one difficulty respecting the occurrence of *Pentacrinus naresianus* at Station 210. For while the individuals of this species dredged at Stations 170 and 214 had the dusky purple colour of acid pentacrinin, those supposed to have been obtained at Station 210 were almost colourless, and the pentacrinin, though present, entirely masked.

[1] On the Colouring Matters of various Animals, and especially of Deep-sea Forms dredged by H.M.S. Challenger, *Quart. Journ. Micr. Sci.* 1877, vol. xvii., N. S., pp. 5–10.

The other species, besides these two which were dredged at Station 214, off the Meangis Islands, were *Metacrinus costatus, Metacrinus moseleyi, Metacrinus varians*, and *Metacrinus wyvillii*. As this last also occurred at Station 170, off the Kermadec Islands, it was probably one of those which were coloured dark purple, owing to the presence of acid pentacrinin. Prof. Moseley can give me no clue, however, as to the anomalous form which did not contain pentacrinin at all, but an entirely different colouring matter. It was of a light pink colour when fresh, and when treated with absolute alcohol gave a simple, light red solution, with an absorption spectrum totally different from that of pentacrinin.

All Prof. Moseley's spectroscopic observations of the colouring matter of the Pentacrinidæ were made in the Pacific; and it therefore became a matter of some importance to determine the presence of pentacrinin in the Atlantic species of the family. For this purpose Prof. Moseley has been kind enough to examine some of the deeply coloured spirit in which there had been preserved several individuals of *Pentacrinus wyville-thomsoni* that were dredged by the "Porcupine" in 1870, off the coast of Portugal. As might have been expected, the colouring matter proved to be pentacrinin.

A still more interesting point is the presence of this substance in *Holopus*. Immersion of a dry, greenish-black *Holopus* in alcohol for a few minutes yielded a dichroic solution, which gave the characteristic spectrum of pentacrinin. It is more than probable, therefore, that this substance will be found to be present in the four Caribbean species of *Pentacrinus*.

Most species of the Comatulæ "appear to be either usually of a rose colour or of an orange or yellow, running into a yellow-brown or of a dark purple. Both the rose or red and yellow colouring matters are freely soluble in alcohol, and usually in fresh water." The colouring matter of most of them, like that of *Antedon rosacea*, has no characteristic absorption spectrum showing bands. But a dark purple species common at Cape York yielded a special colouring matter which Prof. Moseley has termed "Antedonin." It is freely soluble in weak spirit, and gives an intense fuchsin-coloured solution, which yields spectrum consisting of three well defined absorption bands.

I have little doubt that the species in question was *Actinometra strota*. Two species of *Antedon* which were also obtained at Cape York, but in less abundance, seem to have been tinged with the same colouring matter, as their appearance is the same as that of the *Actinometra*. The most remarkable point about this colouring matter is its presence in a slightly modified form in various deep-sea Holothurians.

VII.—ON THE HABITS OF RECENT CRINOIDS, AND THEIR PARASITES.

The Crinoids, like the other Echinoderms, are very gregarious in their habits. This is especially the case with those living near the shore and in depths down to 150 fathoms. In Torbay, at Roscoff, in the Bay of Naples, and in many other places large quantities of *Antedon rosacea* may be readily obtained. Ten thousand individuals of *Antedon dentata* are estimated by the officials of the U. S. Fish Commission to have come up at one haul of the dredge off the coast of New England.[1] The "Porcupine" dredged *Antedon phalangium* in abundance in 50 to 100 fathoms off the Tunis coast; while the Challenger found *Antedon carinata* to be very plentiful off the coast of Bahia. Numerous examples of *Actinometra jukesi* and *Actinometra strota* were dredged at Cape York, and large quantities of both genera have been obtained in the shallow water round the Philippines by Semper, Meyer, and the Challenger. Station 192, near the Ki Islands (140 fathoms), and Station 214, off the Meangis Islands (500 fathoms), proved to be very prolific, both in Comatulæ (12 and 7 species), and in Pentacrinidæ (4 and 6 species); and the dredgings of the "Blake" in the Caribbean Sea have yielded similar results. A few stations where Comatulæ were especially abundant (off St. Vincent, Grenada, and Montserrat, all 120 fathoms or less) also yielded several examples of *Pentacrinus*. Prof. Agassiz records that on one occasion no less than one hundred and twenty-four individuals were obtained at a single haul of the bar and tangles.[2]

On the other hand, the score of individuals of *Pentacrinus wyville-thomsoni* dredged by the "Porcupine" in 1870 in 1095 fathoms off the coast of Portugal were unaccompanied by Comatulæ. This is perhaps due to the depth being one at which these Crinoids are comparatively rare; as two species were obtained, together with fragments of *Pentacrinus*, within a few miles of this Station, where the depth was 350 fathoms less. Some thirty individuals were taken by the "Talisman" in 1883 at a depth of 1480 metres (800 fathoms); but no information respecting the presence or absence of Comatulæ at the same Station has yet been published.

The Bourgueticrinidæ, like the Pentacrinidæ, are generally found living in large numbers together. Both Sars and Verrill have obtained numbers of specimens of *Rhizocrinus* at a single haul of the dredge, and Agassiz records that "on one occasion off Sand Key the dredge must have passed through a forest of them, judging at least from the number of stems and heads of all sizes which it contained."[3] *Bathycrinus aldrichianus* was found by the Challenger to be equally plentiful in the Southern Ocean (Stations 146, 147); and it is evident that in certain localities Crinoids of the more common genera may be obtained in almost any quantity.

[1] *Amer. Journ. Sci. and Arts*, vol. xxiii. p. 136.
[2] *Bull. Mus. Comp. Zoöl.*, 1879, vol. v. p. 296.
[3] *Bull. Mus. Comp. Zoöl.*, 1879, No. 1, vol. v. p. 5.

It is well known that the Crinoids were equally plentiful in several former geological periods. In the British area, for example, there are the remains of enormous forests of Crinoids both in the Silurian and in the Carboniferous rocks. The marvellous abundance of these animals in beds of the same age in America is well known. In a less degree also the Silurian of Sweden, the Devonian of the Eifel, and the Carboniferous of Belgium and Russia were characterised by a great development of Crinoid life. This terminated, however, with the close of the Palæozoic epoch; but in the Lower and Middle Lias, both of Britain and of the Continent, there were enormous colonies of *Extracrinus*, slabs of which are so well known in every museum. Although the limestone bands which are made up of the fragments of the skeleton of *Extracrinus* are by no means so thick as the Palæozoic Crinoidal limestones, yet the association in one place of a large number of individuals must have been, for the time at least, as considerable as in the case of the Palæocrinoids. A similar band, 10 to 20 centimetres thick, which was discovered by M. Eudes-Deslongschamps in the Great Oolite at Soliers near Caen,[1] is evidence of a singularly localised colony or "Station" of *Pentacrinus* (*Extracrinus?*). For no trace of a similar bed occurs in other sections of the Great Oolite in the neighbourhood. Another horizon at the top of the Great Oolite, near Sennecey-le-Grand,[2] is marked by the very great abundance of a species of *Extracrinus* which is also found in corresponding beds elsewhere (in the Department de la Meurthe); while the Forest Marble of Gloucestershire contains numerous remains of Pentacrinidæ which occur associated in slabs much like those formed by *Extracrinus briareus*, though somewhat less extensive.

Although the Middle and Upper Jurassic rocks of this country and of the Continent have been found to contain numerous species of *Pentacrinus*, I do not know that any large forests of them have been met with, like those of the Lias, Great Oolite, and the Recent Seas; and the same may be said of the Cretaceous and Tertiary beds.

As regards the Apiocrinidæ, the abundance of *Apiocrinus parkinsoni* in the Bradford clay is well known, and the Sequanien (Coral Rag) of the Continent is exceedingly rich in *Millericrinus*. The same is true of *Eugeniacrinus* in the White Jura of Wurtemberg, though it does not occur in Britain at all. The coral bed at Nattheim is famous for the number of *Comatula*-remains which it contains; though as these, like the *Eugeniacrinus*-calyces, are all more or less rolled and fragmentary, we do not meet with evidence of gregarious habits such as is represented by either of the colonies of Lyme Regis, Soliers, or Sennecey-le-Grand.

The different modes of attachment which occur among the Crinoids have been discussed in Chapter II. In all the Bourguetierinidæ there is a spreading root of variable extent, the subdivisions of which attach themselves by calcareous expansions to foreign bodies. *Holopus* is a permanently fixed type like the Bourgueticrinidæ. But the

[1] Études sur les étages jurassiques inférieurs de la Normandie, Paris, 1864, pp. 229, 235.

[2] See de Loriol, Notice sur le Pentacrinus de Sennecey-le-Grand, *op. cit.*, pp. 11–13.

Pentacrinidæ are very variable in this respect, some individuals remaining fixed throughout life; while others become detached and are henceforward more or less free like the Comatulæ, attaching themselves temporarily by means of their cirri.

Some Comatulæ, however, lose their cirri altogether when mature. The older ones gradually drop off without being replaced, while their sockets become obliterated until nothing remains of the centro-dorsal but a flat plate in the centre of the radial pentagon. This is the case with the *Actinometra jukesi*, *Actinometra stellata*, and the fossil *Actinometra lovéni*. Some specimens of *Millericrinus pratti* reach the same condition, nothing remaining of the stem except a pentagonal disk in the centre of the ring of basals; so that in the absence of other stalked individuals these would naturally be taken for Comatulæ. This suggests the question whether the single plate in the centre of the calyx of *Marsupites* and *Uintacrinus* may not be really a separated top stem-joint, and not a dorso-central plate homologous with that of Urchins and Stellerids as is generally supposed.

It is noteworthy that certain Blastoids, *e.g.*, *Eleutherocrinus* and *Astrocrinus*, were stemless and free just like *Marsupites;* and it is possible that the same was the case with some species of the Palæozoic genus *Agassizocrinus*, at any rate in later life. Other Palæocrinoids, together with some Blastoids and Cystids, must have been almost equally free, as has been already explained in Chapter II. For though a stem was present, it was often quite short, and almost or entirely devoid of cirri; though it was sometimes fixed by coiling itself round other Crinoid stems and similar bodies.

The apparently perfect freedom of many of these forms is very singular and difficult to understand. Much would be learnt about them, no doubt, if the habits of a living *Actinometra jukesi* were carefully watched, for it is well established that Comatulæ which have once anchored themselves by their cirri remain so fixed for a considerable time, except perhaps at the period of sexual activity; and it would therefore be very interesting to know how far the cirrus-less forms remain permanently fixed. Seaweeds, Polyzoan colonies, Corals, and Zoophytes often serve as the anchorage of Comatulæ. Thus in one case that I have met with the cirri were coiled round a *Dendrophyllia*, and in another round the stem and branches of a *Gorgonia;* while it sometimes happens that the cirri of a *Comatula* are fastened round the still larger cirri of a *Metacrinus* or *Pentacrinus*.

The food of a Crinoid is considerably varied in its nature according to the character of the sea-bottom on which it lives. The horny casings of *Entomostraca* and the larvæ of larger *Crustacea* are frequently to be found in the digestive tube, together with the frustules of Diatoms, spores of Algæ, &c. Dr. Carpenter mentions *Peridinium* (*Ceratium*) *tripos*, Ehr., as a principal article of food of the Arran Comatulæ; while in sections of *Bathycrinus*, *Rhizocrinus*, and *Pentacrinus* from deeper water the siliceous shells of Radiolarians may be found in considerable abundance and variety. Foraminifera too form a staple article of food for these deep-sea species. I have frequently found *Globigerina*, *Biloculina*, and other types beneath the covering plates of the food-grooves on

the arms and pinnules; while remains of their sarcode bodies occur in the intestine of decalcified specimens. Dr. Carpenter mentions the frequent presence in the alimentary canal of *Antedon rosacea*, so as almost completely to choke it, of the body of a suctorial Crustacean with its egg masses;[1] and he supposes "that it has been introduced either as an egg or as a larva, and has undergone its development parasitically where it is found." The same explanation will probably account for the frequent presence in the anal tube of *Actinometra jukesi* and *Actinometra strota* from Cape York of an Isopod (*Anilocra*) nearly half an inch long (Pl. LV. fig. 1). Either as an egg or as a larva it must have been caught in one of the ciliary currents converging on the mouth from the arms, and have then been carried through the digestive tube to the rectum where it remained.

A third form of parasitic Crustacean is one which I have found encysted in the ventral perisome of the disk of some individuals of *Antedon eschrichti* which have been cut into sections; but though one or two accomplished zoologists have examined its remains, I have not been able to learn anything about its affinities. Another equally obscure internal parasite of the Crinoids is a peculiar worm which I first found in some sections of *Actinometra parvicirra* that were cut some years ago in the zoological laboratory of the University of Würzburg. The Crinoid had been obtained in the Philippine Islands by Prof. Semper, and I found three individuals acting as hosts to this singular and entirely unknown creature, which I have not met with in any other Comatulæ from the same locality. It was first noticed in the cœliac canal of the arms, which it often almost filled, so as to suggest the idea that the egg had been introduced into the body-cavity and had developed in that part of it (Pl. LXI. fig. 4). I subsequently found it in the visceral mass of two other individuals, occupying some of the meshes in the connective tissue network which fills up the intervisceral cœlom.

The external parasites of the Crinoids are many and various; though it may be doubted whether some of them can be considered as real parasites, *i.e.*, as living at the expense of the Crinoid. Besides the well known *Myzostoma*, of which I will speak later, Willemoes Suhm found four other parasites on one *Comatula*, all resembling it in coloration.[2] "Es waren das erstens auf dem Kelch sitzende Ophiuriden, zweitens kleinere Aphroditaceen, drittens Amphipoden,[3] die sich in den Magensack eingebohrt hatten und viertens ein Alpheus. Mit Myzostomum also fünf Parasiten auf dieser allerdings sehr grossen *Comatula!*"

I have frequently found Ophiurids entangled in the cirri, which is probably merely accidental; while small bivalves, Sertularian Hydroids, Polyzoa, tube-worms, and corals (Pl. LI. fig. 8) may be attached to the stem, not for any special nutritive purposes, but simply because the larvæ had to find a resting-place somewhere.[4] Various

[1] *Phil. Trans.*, 1866, p. 701.

[2] *Zeitschr. f. wiss. Zool.*, 1876, Bd. xxvi. p. lxxix.

[3] Probably the same as the Isopod above mentioned.

[4] The same may be said of an Ophiurid larva, which was attached by its long Pluteus-arms to the solitary stem-fragment of *Metacrinus tuberosus* from near the Ki Islands (Station 192).

species of Cirripedes are also frequently met with on the stems and cirri of Pentacrinidæ (Pl. LII. fig. 1), both in the Caribbean Sea and in the East Indian Archipelago. Thus, for example, *Scalpellum album* is common on the stem and cirri of many individuals of *Metacrinus* dredged off the Ki Islands (Station 192), while *Scalpellum balanoides* and also *Verruca nitida* occur attached both to *Pentacrinus* and *Metacrinus* from off the Meangis Islands (Station 214). At this last Station too, an obscure larval Cirripede occurred, attached to a cirrus of *Metacrinus varians* by its ventral margin, while a minute *Avicula* was anchored by a few threads to a cirrus of *Metacrinus interruptus* at Station 209. Von. Graff has described a small *Stylina*[1] as parasitic on the anal tube or pinnules of *Antedon rosacea*, and found that holes remained after its removal. *Rhizocrinus lofotensis* in like manner is often infested with two or three small shells of *Stylifer* which bore comparatively large holes in its calyx. Pourtalès has described some examples of this species from the Florida Channel as having the calyx and part of the stem coated with an encrusting Hydroid polype; and some small Rhizopods are shown in Pl. X. fig. 16 on the stem of a *Rhizocrinus rawsoni* from the Azores. I have found *Truncatulina lobatula* to be abundant on the cirri of the Comatulæ which were obtained by the Dutch Arctic Expedition in the Barents and Kara Seas; while *Polytrema miniaceum* is common on the stem and cirri of the Pentacrinidæ dredged at Stations 192 and 214.

The especial parasite of the Crinoids, however, is the well-known *Myzostoma*,[2] which is sometimes found infesting them in great numbers. I have myself removed five moderately large specimens from a single individual of a *Bathycrinus aldrichianus*, and as this had been some years in spirit before reaching me, it may very likely have served as host to a still larger number; while in the Mediterranean twenty-seven have been found infesting a single *Comatula*. They attach themselves to the stem, disk, and arms, either on the ventral or on the dorsal surface. I am not aware that they have ever been met with on *Rhizocrinus*, which often supports boring Stylifers; but v. Willemoes Suhm found them on *Hyocrinus*, *Bathycrinus*, and on many Comatulæ, though he did not meet with free Myzostomida on any of the Challenger Pentacrinidæ. A closer examination, however, has revealed their presence in a few cases. The abnormal specimen of *Metacrinus angulatus* from the Ki Islands (Station 192), which is figured on Pl. XXXIX. fig. 2, had a *Myzostoma wyville-thomsoni* resting between the ordinary anal tube and the second smaller one at its side. In many cases the *Myzostoma*, instead of living in the free state, causes an abnormal growth of the calcareous tissue of the arm so as to form a cyst in which two or three individuals live. At two Stations in the South, and at another in the North Pacific, these cysts proved to be tolerably common. At the first named (Nos. 170 and 174) the cysts were limited to the arms of four Comatulæ; while at

[1] Stylina comatulicola, ein neuer Schmarotzer der Comatula mediterranea, *Zeitschr. f. wiss. Zool.*, 1875, Bd. xxv., Suppl., pp. 124–126.

[2] For a full account of the Myzostomida, see Prof. L. v. Graff, Das Genus Myzostomum, and Zool. Chall. Exp., part xxvii., 1884.

the last (Station 214, off Meangis Islands) the principal hosts were *Antedon angusticalyx* and *Pentacrinus alternicirrus*, several examples of the latter being remarkable for the number of cysts on their arms. Two views of one of these cysts are shown in Pl. XXVII. figs. 7, 8, in the former of which the edge of the parasite is just visible at the opening of the cyst. This cyst is principally formed round a pinnule; but the same kind of thing is sometimes formed in the substance of the arm itself, as shown in Pl. XXVII. figs. 9 and 10, the inhabitant of the cyst being again visible through its mouth.

Thus then, while *Stylifer* bores holes into the calyx of a Crinoid, *Myzostoma* produces swellings and inequalities of growth in the arms and pinnules. I have never met with any distortion of the stem which could be considered as resulting from the action of a parasite; and it is therefore curious that abnormal growths in the stems of fossil Crinoids should have attracted the attention of so many palæontologists. Rofe showed, for example, that one cause of the enlargement of the stems of Carboniferous Crinoids arose from the attachment of a parasitic coral, and the subsequent endeavours of the Crinoid to envelop the latter by an undue secretion of calcareous matter.[1] It has also been shown by Mr. R. Etheridge, jun.,[2] that a similar distortion may be due to the adherence of certain Brachiopods (*Productus* or *Chonetes*). These grew less quickly than their hosts, and so became gradually surrounded and enveloped by the calcareous deposit secreted by the latter. The attachment of Polyzoa, again, may also give rise to enlargement, and even the accidental approximation of the stems of two individuals seems to have sometimes resulted in a complete but irregular union between them. Enlargement and irregularities of growth seem to be very common in the stems of *Apiocrinus* and *Millericrinus*, though not in *Pentacrinus;* and they have often been regarded as the results of injury. But their exact nature and causes have not yet been determined as satisfactorily as in the case of the Palæocrinoids.

There are, however, some stems of *Millericrinus* figured by de Loriol,[3] from the Jurassic rocks of France and Switzerland, which present characters of the same nature as those shown on the arms and pinnules of *Pentacrinus alternicirrus* (Pl. XXVII. figs. 7–10), *i.e.*, cystiform enlargements, each with an external opening. Both Prof. L. von Graff and myself are inclined to regard these as due to the action of *Myzostomida* or of similar parasites. But it is singular that they should be developed on the stem; for I have never found a *Myzostoma*-cyst on the stem of any recent Crinoid, though at some Stations (170, 214) they were abundant upon the arms, both of Comatulæ and of Pentacrinidæ.

[1] Note on the Cause and Nature of the Enlargement of some Crinoidal Columns, *Geol. Mag.*, vol. vi. p. 351.

[2] Observations on the Swollen Condition of Carboniferous Crinoid Stems, *Proc. Nat. Hist. Soc.*, Glasgow, vol. iv., 1879, pp. 19–36, pls. i., ii.

[3] Swiss Crinoids, pl. xi. figs. 18, 36–38. French Jurassic Crinoids, pl. 65, figs. 4–6, 8; pl. 80, figs. 2, 2*a*, 13; pl. 99, figs. 5*a*, 5*b*, 5*d*.

VIII.—THE GEOGRAPHICAL AND BATHYMETRICAL DISTRIBUTION OF THE CRINOIDS.

A. Geographical Range.

The geographical distribution of the Crinoids is fully as extensive as that of the other Echinoderms. Comatulæ range between the two parallels of 81° N. and 52° S., while the corresponding limits for the stalked Crinoids are 68° N. and 46° S. Some genera, such as *Actinometra* and *Pentacrinus*, occur in shallow water everywhere, or almost everywhere, within the tropics; though *Pentacrinus* has not yet been obtained in the Pacific east of long. 170° W., nor between the meridians of 5° W. and 120° E., its nearest approach to the Indian Ocean being the Moluccas. *Metacrinus*, on the other hand, has been found in the neighbourhood of Singapore; but is otherwise almost entirely limited to the tropical regions of the West Pacific, ranging, however, as far north as Japan; while *Pentacrinus wyville-thomsoni* occurs in the Atlantic as far north as lat. 45°. *Holopus*, however, has never been obtained out of the Caribbean Sea.

Of the stalked Crinoids *Rhizocrinus* has the farthest northern range (68° N.), but it has not been met with more than once (Station 122), or possibly twice (Station 323), south of the equator, and is limited to the Atlantic and the Caribbean Ocean. *Bathycrinus*, while ranging through 110° of latitude in the Atlantic and Southern Oceans, does not occur in the Pacific at all. *Antedon*, on the other hand, is cosmopolitan, five species inhabiting the Arctic Ocean, while the genus is also well represented in the Southern Ocean. It is curious, however, that so far as I am aware, there are no museum specimens, nor any records of Comatulæ from New Zealand.

As a general rule, the individual species of Crinoids are much limited in their range, though there are a few well marked exceptional cases. Both species of *Rhizocrinus* occur in the east as well as in the west Atlantic, *Rhizocrinus lofotensis* ranging from the Lofoten Islands to 9° S. or perhaps to 35° S.; while three species of Pentacrinidæ occur in the South Pacific near the Kermadecs, and also among the Philippines, as the following list shows:—

Species.	Near the Kermadec Islands.		Near the Fiji Islands.	Panglao.	Meangis Islands.
Pentacrinus naresianus, . .	170	171	175	210?	214
Pentacrinus alternicirrus, . .	...	171	...	210?	214
Metacrinus wyvillii, . . .	170	...	...	...	214

The four Caribbean species of *Pentacrinus* are widely distributed among the West India Islands; and it is possible (or rather probable) that systematic dredgings among the islands of the Pacific, like those of the "Blake" in the Caribbean Sea, would largely increase the specific range both of *Pentacrinus* and of *Metacrinus*.

Among the Comatulæ the well known *Antedon eschrichti* is universally distributed in the Arctic Ocean, and on both sides of the Atlantic as far south as lat. 43° N.; while *Antedon dentata* of the Barents Sea, the north-east Atlantic, and the Scandinavian coasts is abundant on the banks off New England. *Antedon carinata* is another widely distributed species, occurring both on the Atlantic and on the Pacific coasts of South America, at Java, Mauritius, the Seychelles, and elsewhere; while *Actinometra pulchella* of the Caribbean Sea has also been dredged in moderately deep water off the coast of Moroeco.

The greater number of the Comatulæ, however, like the four species of *Bathycrinus*

TABLE II.—*Showing the Geographical and Bathymetrical Range of all the Genera of Recent Crinoids.*

Genus.	Depth.	Temperature.	Latitude.	Oceans.	Remarks.
	Fathoms.	°C.			
Pentacrinus, . .	42–1350	1·8–20	46° N.–30° S.	A.C.P.E.[1]	... ...
Metacrinus, . .	68–630	4–21·7	35° N.–30° S.	P.E.	... ...
Rhizocrinus, . .	73–1900	0–21·5	68° 15′ N.–35° 39′ S.	A.C.	A stem-fragment only at St. 323, 1900 fath. Lat. 35° 39′ S. (*fide* C.W.T.)
Bathycrinus, . .	1050–2435	0·8–2·5	65° 55′ N.–46° 46′ S.	A.S.	... ...
Hyocrinus, . . .	1600–2325	0·8–1·8	5° 31′ N.–46° 16′ S.	A.S.E. ?	A young specimen, perhaps of *Hyocrinus*, from St. 223, in N.W. Pacific, 2325 fath. (*fide* C.W.T.).
Holopus, . .	About 100	...	10°–20° N.	C.	... ...
Antedon, . .	2–2900	0·2–25	81° 41′ N.–52° 5′ S.	A.C.S.I.P.E.	
Actinometra, . .	2–533	8·5–25	35° N.–35° S.	A.C.I.P.E.	Temperature at greatest depth, 533 fath., not known.
Eudiocrinus, . .	30–1050	2·4–4·2	45° N.–37° 34′ S.	A.P.E.	Highest temperature in shallow water among the Philippines not known (*Eudiocrinus indivisus*).
Promachocrinus, .	28–1800	0·3–5·3	4° 33′ N.–50° 1′ S.	S.P.	One specimen at St. 214, in N.W. Pacific.
Atelecrinus, . .	291–610	3·7–8·5	24° 8′ N.–19° 10′ S.	A.C.P.	Lowest limit (St. 174) uncertain. Possibly not below 450 fath.
Thaumatocrinus, .	1800	0·3	50°·1 S.	S.	... ...

[1] A. Atlantic. C. Caribbean Sea. S. Southern Ocean. I. Indian Ocean. P. Pacific. E. The more or less enclosed seas of the East Indian Archipelago, between Cape York and Singapore. Within this limit are comprised Stations 201 to 212, in the neighbourhood of the Philippine group, but not Station 214, off the Meangis Islands.

and most of the Pentacrinidæ, have as yet been obtained at one or two localities only, and those not very widely separated.

Table II. on the preceding page gives the bathymetrical and geographical ranges, so far as yet known, of all the genera of recent Crinoids; their distribution in the various oceans being indicated by the capital letters in the fourth column. A few cases of uncertainty, owing to deficiency of information and other causes, are noted under the head of remarks.

B. Bathymetrical Range.

The frequency of occurrence of all the genera of recent Crinoids at depths below 250 fathoms, so far as has yet been made known, is shown in Table III. One or two curious

Table III.—*Showing the Frequency of Occurrence of all the Genera of Recent Crinoids at depths below 250 fathoms.*

Genus.	200–500 f.	500–700 f.	700–1200 f.	1200–2000 f.	2000–2500 f.	2500–2900 f.	Remarks.
Pentacrinus, . .	7	6	2	1	...	...	Only four of the seven dredgings noted in the first column were at a greater depth than 250 fath.
Metacrinus, . .	1	1	...	...	...	...	... ...
Rhizocrinus, . .	10	8	5	2	...	...	A stem-fragment only at St. 323; 1900 fath. Lat. 35° 39′ S. (*fide* C.W.T.).
Bathycrinus, . .	...	...	4	4	1	...	... ...
Hyocrinus, . .	...	...	...	2	1?	...	Possibly a young specimen from St. 223, in N.W. Pacific, 2325 fath. (*fide* C.W.T.).
Holopus, . .	...	...	...	...	...	...	... ...
Antedon, . .	16	6	4	2	...	2	At three of the Stations recorded in the first column (for each genus) the depth was between 200 and 250 fath. Stations 174B, C, D (255, 610, and 210 fath.) are not recorded at all for either genus, owing to want of information.
Actinometra, . .	5	1	..	...	...	...	
Eudiocrinus, . .	1	2	2	...	...	...	... ...
Promachocrinus, .	1	...	...	2	...	...	... ...
Atelecrinus, . .	7	1?	...	...	...	...	Lowest limit (Station 174C; 610 fath.) uncertain. Possibly not below 450 fath.
Thaumatocrinus, .	...	...	...	1	...	...	... ...

contrasts are noteworthy. While *Bathycrinus* and *Hyocrinus* are essentially abyssal forms, *Actinometra* is not known with certainty to occur below 533 fathoms, and has not been obtained more than seven times below 200 fathoms.[1] *Pentacrinus*, having a

[1] Comatulæ were dredged at Stations 174B, 174C, 174D, the depths being respectively 255, 610, and 210 fathoms; but there is no record of the particular haul which yielded the Comatulæ.

much wider geographical range than *Metacrinus*, also extends to a greater depth; while the same contrast, including also thermal range, may be noticed between *Antedon* and the stalked Crinoids generally. It is somewhat singular that this widely distributed genus, which was dredged at 2900 fathoms in the Pacific and at 2600 fathoms in the Southern Sea, should not have been met with between the latter depth and 1600 fathoms.

C. The Association of the Genera at Particular Stations.

The mode of grouping of the various genera of Crinoids, both stalked and free, which have been obtained at different Stations and by the exploring expeditions of various countries, presents some points of interest. The Challenger dredged Comatulæ at forty-five Stations, and stalked Crinoids at sixteen. If the different North Atlantic expeditions of the British and Norwegian Governments be also reckoned, this last number rises to 28.

A single species of stalked Crinoid was found at several Stations, unaccompanied by any Comatulæ, as shown in the following Table.

Table IV.—*Showing the number of times that Isolated Species of Stalked Crinoids have been Dredged.*

	Rhizocrinus.	*Bathycrinus.*	*Hyocrinus.*	*Pentacrinus.*	*Metacrinus.*
Challenger—	3	1	1 (young? *fide* C.W.T.)	...	1
North Atlantic Expeditions—					
1. British.	7	1	...	1	...
2. Norwegian.	...	4	...	...	...

At eleven Stations during the Challenger and "Porcupine" Expeditions which yielded stalked Crinoids, there were either more than one species, or if only one was obtained it was associated with one or more species of Comatulæ (see Table V.). *Pentacrinus* has been found associated with all the Comatulid genera except *Thaumatocrinus*, which was only obtained once in the Southern Sea, considerably beyond the most southern limit of *Pentacrinus*.

The "Blake," however, dredged *Pentacrinus* in shallower water than was worked by the Challenger; and found it associated with *Actinometra* at nine out of the fifty-four Stations at which stalked Crinoids were obtained (see Table VI.). As in the case of the Challenger and "Porcupine," the two species of *Rhizocrinus* were never found at the same Station.

TABLE V.—*Showing the Association of Crinoid Genera at different Stations occupied by the "Porcupine," Challenger, and "Talisman," together with the number of Species obtained at each Station.*

REMARKS.	Stations.	*Pentacrinus.*	*Metacrinus.*	*Rhizocrinus.*	*Bathycrinus.*	*Hyocrinus.*	*Antedon.*	*Actinometra.*	*Endiocrinus.*	*Atelecrinus.*	*Promachocrinus.*	*Thaumatocrinus.*
Separate hauls at very different depths.	"Porcupine," 1870.	1	...	...	...	...	2	...	...	...	...	...
Metacrinus murrayi and *Pentacrinus naresianus* referred here conjecturally (see p. 128).	Challenger Stations. 210	1?	1?	...	...	...	2	...	...	...	...	...
... ...	175	1	...	...	...	...	3	...	...	...	...	...
... ...	235	1	...	...	...	...	...	...	1	...	...	...
... ...	170	1	2	...	...	...	6	...	...	...	...	...
Separate hauls at slightly different depths.	122	1	...	1	...	...	...	...	...	1	...	...
... ...	171	2	...	...	...	...	...	...	...	...	...	...
... ...	214	2	4	...	...	...	6	...	...	...	1	...
... ...	192	...	4	...	...	...	12	1	...	...	...	...
Hyocrinus, stem only (*fide* C.W.T.).	106	...	...	...	1	1?	...	...	...	...	...	...
... ...	147	...	...	...	1	1	3	...	...	...	1	...
... ...	158	...	...	...	...	...	...	...	...	...	1	1
No information about Comatulæ.	"Talisman," 1882.	...	...	1	...	...	...	...	...	...	...	...
	1883. A.	1	...	...	...	...	...	...	...	...	...	...
	1883. B.	...	...	1	1	...	...	...	...	...	...	...

Table VI. shows the association of *Pentacrinus, Holopus, Rhizocrinus,* and the three Comatulid genera in the Caribbean Sea, together with the number of times that two or more species of *Pentacrinus* were found at the same Station. Comatulæ were obtained some eighty times; but as I have not yet been able to determine them critically, I have found it impossible to give the number of species occurring at each Station, as has been done for the Challenger dredgings.

TABLE VI.—*Showing the Association of Crinoid Genera in the Caribbean Sea, together with the number of times that two or more Species of Pentacrinus were found at the same Station.*

Number of Stations.	*Pentacrinus.*	*Rhizocrinus.*	*Holopus.*	*Antedon.*	*Actinometra.*	*Atelecrinus.*
13	1 species					
12		×				
1	1 „	×				
1	1 „	×		×	×	
3	1 „			×		
3	1 „			×	×	
1	1 „				×	
4	2 „					
1	2 „	×		×		
1	2 „	×			×	
1	2 „			×		
2	2 „			×	×	
1	4 „		×	×	×	
2			×			
1		×		×		
4		×			×	
3		×		×	×	
1		×				×
1		×		×		×
Stalked Crinoids at 56 Stations.	*Pentacrinus* at 32 Stations.	*Rhizocrinus* at 26 Stations.	*Holopus* at 3 Stations (two isolated).	Comatulæ at 82 Stations altogether.		

The above Table embraces—(1) all the dredgings of the U. S. Coast Survey Steamers in the Caribbean Sea and Gulf Stream; (2) those of Captain Cole of the Telegraph Steamer "Investigator;" (3) those carried on at Barbadoes by the collectors for Sir Rawson Rawson; (4) those of a few isolated collectors who have sent specimens to the Museum of Comparative Zoology. The whole series will be found recorded in the Station List at the end of the Report. No attempt has been made to classify any observations anterior to those of Pourtalès in 1867.

IX.—ON THE RELATION BETWEEN THE RECENT AND THE FOSSIL NEOCRINOIDS.

Our knowledge of the Crinoids of the Secondary rocks is largely due to the labours of d'Orbigny, Quenstedt, and de Loriol, the last of whom, having completed an elaborate Monograph on the Fossil Crinoids of Switzerland, is now publishing a still more extensive one devoted to those occurring in the Jurassic rocks of France.

He groups the Neocrinoids into ten families—

1. Marsupitidæ.
2. Uintacrinidæ.
3. Encrinidæ.
4. Eugeniacrinidæ.
5. Plicatocrinidæ.
6. Apiocrinidæ.
7. Bourgueticrinidæ.
8. Holopodidæ.
9. Pentacrinidæ.
10. Comatulidæ.

The first two of these, each based on a single genus, are placed provisionally among the Neocrinoids by de Loriol, who has transferred them from the Palæocrinoids (= *Tessellata*) with which they were ranked by Zittel. In this step, and also in the establishment of the new family Bourgueticrinidæ for the reception of *Bourgueticrinus*, *Rhizocrinus*, and allied genera, I entirely agree with de Loriol; but I am not disposed to follow him and Zittel in the association of *Hyocrinus* and *Plicatocrinus* into one family, and prefer to consider the former genus as the type of a new family "Hyocrinidæ." It has not yet been discovered in the fossil state; and of the ten families enumerated by de Loriol, the first six in the above list died out at or before the close of the Secondary period; while all the four others have living representatives.

Little need be said about the extinct Neocrinoids, except that the association of the Cretaceous *Marsupites* and *Uintacrinus* with the Palæocrinoids, the so-called *Tessellata*, appears to me to be based on a misconception; and that *Encrinus*, as might be expected from its stratigraphical position, finds its nearest allies in genera of the Carboniferous and not of the Jurassic epoch, as will be pointed out later.

The characters of *Plicatocrinus* are entirely different from those of any recent Crinoid, though its calyx has a singular resemblance to those of young Pentacrinidæ. The Eugeniacrinidæ are a less aberrant group; but though the symmetrical forms of *Eugeniacrinus* appear to have a considerable resemblance to *Rhizocrinus* and *Bathycrinus* in the structure of the lower part of the cup and in the distribution of the canal system, yet such types as *Phyllocrinus* and the distorted *Torynocrinus* are altogether different from any recent Crinoid.

The Apiocrinidæ, represented by some doubtful species in the Lias, flourished exten-

sively through the Jurassic period, and died out in the Lower Neocomian. Their place was taken by the Bourgueticrinidæ, which were formerly associated with them into one family. We have no certain evidence of the occurrence of the typical genus *Bourgueticrinus* in other than Cretaceous rocks; though stem-joints which have been referred to this genus occur both in Jurassic and in Eocene deposits. It is not unlikely, however, that they belong to *Thiollericrinus* or to *Rhizocrinus* respectively. The latter genus, which is represented by two living species, is probably exclusively confined to the Tertiary rocks, except perhaps for the so-called *Bourgueticrinus alabamensis* from the Cretaceous formation of Alabama, U.S.; and some of the stem-joints hitherto referred to *Rhizocrinus* or to *Bourgueticrinus* may possibly belong to *Bathycrinus*, no calyx of which has yet been found in the fossil state.

As regards the fossil Holopodidæ, there are *Micropocrinus* of the Italian Miocene, *Cyathidium* in the Chalk of Faxoe, the singular *Gymnocrinus* in the Oxfordien of France and Switzerland, and lastly in the Middle Lias *Cotylecrinus* and *Eudesicrinus;* while *Edriocrinus* from the Upper Silurian and Devonian, a type much resembling *Holopus* in character, is a proof of the great antiquity of these sessile Crinoids.

The Pentacrinidæ are remarkable for their long geological history. The type genus *Pentacrinus* first appears in the Trias, together with the short-lived *Encrinus*. It persisted through the whole of the Secondary and Tertiary periods, and is represented by eight species at the present time. On the other hand, *Extracrinus* with its characteristic stem, dicyclic base, and peculiar arm-divisions is confined to the Lias and Lower Oolites, unless, as I am disposed to think, the *Pentacrinus asteriscus* which has been found in the Western Territories of the United States associated with Alpine Trias fossils and *Spirifera*, is also to be referred to this genus. *Balanocrinus*, known as yet only by stem-joints, ranges from the Middle Lias to the Lower Neocomian. The remaining genus *Metacrinus* is confined to Oceania and the shallower parts of the Pacific, and is at present unknown in the fossil state.

The general character of the fossil Pentacrinidæ is essentially the same as that of their recent representatives, except that they often had much longer stems which sometimes reached as much as 50 or even 70 feet; while the number of arms was frequently limited to ten, which is not the case in any recent species but *Pentacrinus naresianus* (Pls. XXVIII.–XXXa.). Some of them also appear to have been devoid of external basals. But in two cases, at any rate, *Pentacrinus dixoni* and *Pentacrinus fisheri*, this is due to error; for the basals have been overlooked and therefore described as absent.[1]

Three genera of the Comatulidæ, *Antedon*, *Actinometra*, and *Eudiocrinus* are known in the fossil state. The last named is at present limited to the Lower Neocomian of

[1] On the supposed Absence of Basals in the Eugeniacrinidæ and in certain other Neocrinoids, *Ann. and Mag. Nat. Hist.*, 1883, ser. 5, vol. xi. pp. 327–334.

Switzerland; though both the other two genera range back as far as the inferior Oolite, *Antedon* being much the more common. But the distinctions between them, so far as can be made out in the calyx alone, are much less sharp than in recent Comatulæ. Many of the Jurassic species combine in a singular degree various characters which are of considerable value for the generic determination of recent Comatulæ.

Besides their tendency to combine the characters of recent generic types, the Jurassic Comatulæ are remarkable for their large size, as are also the Cretaceous species. The centro-dorsal may reach from 9 to 13 mm. in diameter, which is greater than that of nearly every recent species except *Antedon eschrichti;* while this type and *Actinometra robusta* are almost the only living Comatulæ with arm-bases anything like as massive as those of the fossil species. Some of the Cretaceous forms must have been very large. Thus the united centro-dorsal and radials of *Antedon campichei* from the Neocomian of Switzerland may reach 15 mm. in height and over 20 mm. wide; while several centro-dorsals of *Antedon* from the Upper Chalk are almost equally gigantic.

The Eocene fossils are of moderate size; but the Miocene *Antedon rhodanicus* has a centro-dorsal 13 mm. in diameter, while the three species described by Forbes from the Coralline Crag of Sutton are all considerably smaller.

Of the remaining Comatulidæ neither *Promachocrinus* nor *Thaumatocrinus* has yet been found fossil; and though specimens have been described from the Maestricht Chalk with a complete basal ring,[1] I should hesitate at present to refer them to *Atelecrinus*.

[1] *Zeitschr. d. deutsch. geol. Gesellsch.*, Jahrg. 1878, p. 66.

X.—ON THE RELATIONS OF THE NEOCRINOIDS TO THE PALÆOCRINOIDS.

The term "Neocrinoidea," which was first introduced by the writer in 1881,[1] embraces all the "Crinoidea Articulata" of Miller and Müller, together with *Marsupites* and *Holopus*, both of which were placed elsewhere by the German zoologist; while the Palæozoic Crinoids generally were referred to by him as the "Crinoidea Tessellata,"[2] this group including the Semiarticulata and Inarticulata of Miller. His definitions of these two great groups, however, were meagre in the extreme. The Articulata comprised the genera *Pentacrinus, Apiocrinus, Encrinus*, and *Comatula* in the wide sense, *i.e.*, types in which the radii are free down to the base of the calyx; while his only distinct reference to the Tessellata is that they are Crinoids "deren Kelch ganz aus Tafeln zusammengesetzt ist."[3] From his numerous references to individual genera, however, it is possible to obtain a tolerably clear notion of the ideas which led Müller to establish these two principal divisions of Crinoids; and various palæontologists have in consequence attempted, with more or less success, to formulate characters which should distinguish them from one another.

The most satisfactory of the earlier attempts in this direction was that which appeared in Bronn's Thierreich (vol. ii. p. 228). Besides the supposed sutural union of the calyx-plates and the presence of a subtegminal mouth in the Tessellata, reference is also made to the asymmetry of the calyx in this group, the more frequent presence of a dicyclic base, and the greater rarity of stemless forms than in the Articulata.

On the other hand, Lütken[4] and others have pointed out the weakness of these definitions.

By far the best of the numerous diagnoses which have been drawn up since the time of Müller are those which we owe to Zittel.[5] But the freedom of the rays in the Articulata, on which Müller laid stress, is omitted by him, while an important error runs through his as through all the earlier definitions. The calyx plates of the Tessellata are "unbewëglich durch einfache Nähte verbunden;" while those of the Articulata are "meist sehr dick, durch gelenkartig ausgehöhlte und gewölbte oder ebene Nahtflächen verbunden." Now the lowest articulation to be found in the calyx of an articulate Crinoid is that which unites the first and second radials (Pl. LXII.). The former are suturally united both to one another and to the basals; while, when underbasals are present (*Marsupites, Extracrinus*), the union between them and the basals is of the same kind. In both groups the interradials (when present) are suturally united to the radials and to one another; so that the name-giving difference between the Articulata and the Tessellata is

[1] *Ann. and Mag. Nat. Hist.*, 1881, ser. 5, vol. vii. p. 296.
[2] Pentacrinus, *loc. cit.*, p. 30.
[3] *Ibid.*, p. 29.
[4] *Op. cit.*, pp. 219–222.
[5] Palæontologie, pp. 335, 342, 345.

reduced to a supposed difference in the mode of union of the first radials with the joints which they bear.

In all the Mesozoic and later Crinoids this is an articulation effected by a pair of muscles and three ligaments, as described above (Pl. VIIa. fig. 15; Pl. VIIb. figs. 1, 5; Pl. VIIIa. fig. 7; Pl. X. figs. 1–4; Pl. XII. figs. 9, 12, 15, 20, 23; Pl. XX. figs. 7, 8; Pl. XXI. figs. 5*c*, 6*d*; Pl. LXII.). It presents itself even in forms which have such decided Palæozoic affinities as *Hyocrinus*, *Marsupites*, and *Thaumatocrinus*, but it appears, according to de Loriol,[1] to be absent in *Guettardicrinus*, in which type the reduced articular facet found in *Apiocrinus* seems to have disappeared altogether, not only from the distal faces of the first radials, but also from those of the axillaries.

In this respect, therefore, as also in the presence of numerous interradials, and in the close lateral union of the lower parts of the rays, *Guettardicrinus* is a true Tessellate, as has been already pointed out by Lütken.[2]

On the other hand, the first radials of many of the so-called Tessellates have just as well-marked articular facets as those of the Pentacrinidæ, and the joints belonging to the other orders of radials are united to one another in just the same way as the distichals and palmars of Pentacrinidæ and Comatulæ. *Marsupites*, *Allagecrinus*, and *Platycrinus* are notable examples of the presence of a muscular joint between the first and second radials; and I feel confident that it would be found to recur in numerous other forms with perforated first radials, such as *Cyathocrinus*, *Poteriocrinus*, and *Myrtillocrinus*, if properly looked for.

Thus then, so far as regards the presence or absence of a true articulation between the first and second radials, no hard and fast line can be drawn between the older and the younger Crinoids. Many of the former certainly had a muscular joint in this position; while it was absent in *Guettardicrinus*, though not from an arrest of development, as in the older Crinoids.

The want of a distinct articular facet on the first radials of many Tessellata is only another indication of their being in the condition of permanent larval forms, as is so clearly shown by many of their other characters.[3] The fossæ for muscles and ligaments, the central canal, and the transverse articular ridge of the radials and arm-joints of all the post-Palæozoic Crinoids (except *Guettardicrinus*) only make their appearance at a comparatively late developmental stage. The axial cords of the young joints, whether of rays, arms, or pinnules, lie at first upon their upper surfaces, eventually being received more deeply into the substance of the plates. They lie for some time in open canals, which are only closed up and received into the substance of the skeleton at a later period. Consequently the transverse section, which at first resembles a horse-shoe, finally comes to be a ring, with muscles and ligaments attached round it. Now in many

[1] Paléont. Franç., *op. cit.*, pp. 216, 218.

[2] *Op. cit.*, p. 221.

[3] See Wachsmuth, *Amer. Journ. Sci. and Arts*, vol. xiv. p. 190.

Palæocrinoids the distal faces of the radials remain permanently in the horse-shoe condition, and the ligaments and muscles must therefore have remained small and poorly developed, just as they are in recent Crinoids until the central canal is completely closed in. The gradual development of complete articular facets, commencing before the horse-shoe stage, has been traced in the radials of the Palæozoic *Allagecrinus*, just as in the Comatulæ;[1] and I see therefore no reason to doubt that many Palæocrinoids had an imperfect articulation and not a suture between the horse-shoe facets of the first two radials. This may perhaps be correllated with the small development of the arms of the Palæocrinoids, relatively to that of the calyx. The integrity of long arms with two hundred or three hundred joints, like those of many Comatulæ, would be much more perfectly preserved if the bundles of muscles and ligaments were large and well developed than if they remained small, as must necessarily be the case on an imperfect terminal facet of a semicircular or horse-shoe shape.

Believing then that in a very large number of the Palæocrinoids the second radials were at least as movable on the first as in *Apiocrinus*, and in some cases a good deal more so, I cannot regard the "differentia" of the Palæozoic and the later Crinoids on which Müller and his followers laid so much stress, as a point of great systematic importance.

Wachsmuth[2] omits all reference to the mode of union of the plates in his diagnosis of the Palæocrinoidea; and had it not been revived by Zittel as a means of distinguishing the two great groups, Müller's name would long ago have fallen into disuse.

The name Palæocrinoidea was proposed by Wachsmuth[3] in 1877 to denote "all true Crinoids in which the actinal side is closed;" but it was not actually defined by him until two years later, nearly simultaneously with the appearance of Zittel's classification. He regards the group as of sub-ordinal value, and as specially distinguished by two characters—(1) the interradials constitute important elements of the test; (2) the absence of external food-grooves or oral aperture. He proposed incidentally to group the later Crinoids together under the name "Stomatocrinoidea"; but he did not attempt to define the group; and so far as I am aware, this name has not been adopted by systematic zoologists, while Wachsmuth himself is now inclined to abandon it. Various reasons, which will be explained more fully subsequently, have induced the writer to propose the name of "Neocrinoidea" for the Mesozoic and later Crinoids. This has been adopted by Prof. Zittel, and also by de Loriol in his work on the French Jurassic Crinoids, and it will be used throughout these Reports.

Although *Marsupites* is ranked among the Tessellata by Müller, and also, together with *Uintacrinus*, by Schlüter and Zittel, I can see no reason for excluding these two

[1] *Ann. and Mag. Nat. Hist.*, 1881, ser. 5, vol. vii. pp. 283–287.

[2] Revision, part i. p. 30.

[3] *Amer. Journ. Sci. and Arts*, vol. xiv. p. 190.

types from the group of the Neocrinoids, to which they have been already provisionally referred by de Loriol.

Both have uniserial arms, a symmetrical calyx, and no anal side; while in *Marsupites*, at any rate, the first radials were perforated by canals, and united to the second by muscular joints. Interradial plates, however, are well developed in both genera, especially in *Uintacrinus*. But the upper series of so-called interradial and interdistichal or interaxillary plates are really parts of the radial system, and correspond to the pinnules of free arms, as was pointed out by Meek. At the same time he noted their unusual size, and the fact that they are united with each other and with the main divisions of the rays for some distance up, so as to constitute a part of the walls of the body.[1]

Schlüter,[2] to whom Meek's remarks seem to have been unknown, speaks of this as a possibility, but rejects it on account of the absence of a central canal in the supposed pinnule-joints, and other less important reasons. I cannot help suspecting, however, that the canal will be found, and that the plates in question are really the basal joints of the large lower pinnules. He describes how these plates group themselves together in double rows, the lowest of which "geht aus von dem zweiten Distichalgliede. Sie besteht vielleicht aus 9 Stücken jederseits. Die folgende Doppelreihe, aus kleineren Täfelchen zusammengesetzt, nimmt ihren Anfang vom fünften Stücke über dem Axillare." The first pinnule being on the second brachial, the next on the same side would be on the fourth; but since the third is a syzygial or double joint, the fourth brachial is primitively the fifth above the axillary; while Schlüter's figures[3] show that the double row of interdistichal pieces which "nehmen ihren Anfang vom vierten Distichale aus" are really the pinnules on the epizygals of the two third brachials. There are many species of recent Crinoids (*Pentacrinus, Metacrinus, Actinometra*) which have large lower pinnules with the basal joints closely fitted together just as in *Uintacrinus* (Pl. XXXVIII.; Pl. XXXIX. fig. 1; Pl. XLIII. fig. 2; Pl. LII. fig. 1); so that the supposed resemblance in this respect between *Uintacrinus* and the Palæocrinoids goes for nothing. Apart from these two genera there are no Secondary Crinoids which could by any possibility be referred to the Tessellata; and this is still more emphatically the case with the Tertiary and recent forms. It is true that the most striking characters of the recent *Thaumatocrinus* (Pl. LVI. figs. 1–4) indicate an affinity to early Palæozoic types (*ante*, pp. 39–46); but, considering that *Thaumatocrinus* is a *Comatula*, it is more than probable that this resemblance is not due to any genetic connection.

Thus then I regard the Neocrinoids as constituting a group or subclass which is distinctly marked off from its Palæozoic predecessors. These became extinct with the Palæozoic epoch, like the Blastoids, Cystids, and Palæchinoids. The latter in fact

[1] Grinnel, Note on the genus Uintacrinus, Bull. U.S. Geol. and Geog. Survey of the Territories, vol. ii., No. 4, p. 377.
[2] *Op. cit.*, p. 58. [3] *Op. cit.*, Taf. iv. figs. 1, 3.

constitute a parallel group to the Palæocrinoids, as Urchins are abundant in the Secondary and Tertiary rocks and also at the present time. But the Blastoids and Cystids shared the fate of the Trilobites, and did not persist into the Triassic Seas.

It will now be advisable to discuss the various characters which distinguish the Neocrinoids from the Palæocrinoids. Some of them have been alluded to elsewhere, but no attempt has yet been made to group them together.

In the first place the calyx of a Neocrinoid is very symmetrical in its composition, though it may undergo more or less distortion, as in the Eugeniacrinidæ and Holopidæ (Pls. I.–IV.).

Under-basals are rarely present (*Encrinus*, *Extracrinus*, and *Marsupites*); while by far the greater number of genera have five equal and similar basals, with five equal and similar radials resting upon them. *Hyocrinus* it is true has only three basals (Pl. VI.); while the radials of *Holopus* (Pl. III. fig. 1) and *Eudesicrinus* are not symmetrical; but their want of symmetry is not due to the intercalation of any anal plate as in nearly all Palæocrinoids, so that one side of the calyx becomes especially distinguished as the anal side. In all Neocrinoids, with the single exception of *Thaumatocrinus*, these primary radials are in contact with one another by the entire length of their sides; or more rarely, as in *Guettardicrinus*, *Uintacrinus*, and *Apiocrinus roissyanus*,[1] their distal angles are cut away, so as to receive the lower part of the first interradial. This feature, which is common enough in the Palæocrinoids, is rare in the Neocrinoids; for the second radials are usually wider than the first, and more or less completely united to their fellows by their lower angles (Pl. XV. figs. 1, 2; Pl. XXIX. fig. 1; Pl. XXXVII. figs. 1, 2; Pl. XXXIX. fig. 1; Pl. XLIII. fig. 2; Pl. XLIX. figs. 1, 2).

In like manner there is only one known genus and species of Neocrinoids (*Thaumatocrinus renovatus*, Pl. LVI. figs. 1–4) which has the rays completely separated by primary interradials that rest on the basals; though there are several genera of Palæocrinoids distinguished by this peculiarity, which is characteristic of the large and important family Rhodocrinidæ (Wachsmuth and Springer).

In most Palæocrinoids a certain number of the plates above the primary radials become closely united to one another and to the interradials so as to form the walls of a relatively large and substantial calyx. This is especially the case in the Actinocrinidæ; "while in the Platycrinidæ comparatively few plates are enclosed within the calyx, many of them, which in the Actinocrinidæ form a conspicuous part of the body, being here found in the lateral appendages. In the Platycrinidæ the calyx proper is constructed almost exclusively of basals and first radials, all higher orders of radials either forming a part of the brachial appendages, or, when partially incorporated with the calyx, being insignificant compared with the other parts."[2]

In the Ichthyocrinidæ, however, while the secondary and tertiary radials form a part

[1] See woodcut, fig. 9 on p. 183.

[2] Wachsmuth, Revision, part ii. p. 55.

of the body, they are often connected by a pavement of minute irregular plates, which may commence as low down as the level of the second radials, and are thought by Wachsmuth and Springer to indicate the presence of a flexible perisome. This is especially the case in some species of *Taxocrinus*, the rays of which must have been at least as free as those of many Pentacrinidæ and Comatulæ, and much more so than those of *Apiocrinus* and *Guettardicrinus*. In these two genera, as in *Uintacrinus*, the calyx interradials are not only present but well developed, so as to increase the size and complexity of the cup. In fact the rays of *Guettardicrinus* are immovably united as far as the second brachial, either directly, or by the intervention of interradial plates; while some species of *Apiocrinus* (*Apiocrinus parkinsoni*) have the second and third radials in close lateral contact with their fellows. Other species, however, with the arms free from the radial axillaries, have a well defined pavement of interradial plates, the lowest of which are large and regular and rest on the upper angles of the first radials, as in *Apiocrinus roissyanus*;[1] while the upper ones are smaller and more irregular, and pass gradually upwards into those of the ventral side. The same is the case in *Marsupites*.

Many Pentacrinidæ and Comatulæ have wide rays which are in close lateral contact just as in *Apiocrinus parkinsoni* (Pl. XV. fig. 2; Pls. XVIII., XIX.; Pl. XXV.; Pls. XXVIII.–XXX.), while others have the rays more separated from one another, but united by flexible perisome in which the joints of the lower pinnules and numerous small irregular plates are imbedded (Pl. XIII. fig. 1; Pl. XXXI.; Pl. XXXVII. fig. 1; Pl. XXXIX. fig. 1; Pl. XLIX. figs. 1, 2; Pl. L. fig. 1). These may cease at the level of the third axillaries, or pass up into the plating of the ventral side as in *Apiocrinus roissyanus*, *Marsupites*, and the Liassic species of *Extracrinus*. But they are never so large as in these fossils, and more nearly resemble the small irregular plating of the Ichthyocrinidæ.

Thus then there are many Neocrinoids with no interradial plates in the calyx; and when these plates are present and well defined, as in *Apiocrinus*, *Guettardicrinus*, and *Marsupites*, or *Uintacrinus*, they are not limited to any special side of the calyx, but are equally distributed all round it; so that there is no distinction of the anal side, *Thaumatocrinus* of course excepted.

In the Palæocrinoids, however, the pentamerous symmetry of the calyx is almost always disturbed by a greater or less modification of the plates on the anal side. The difference may be very slight, as in *Phimocrinus* and *Cupressocrinus*, which have the anal opening separating the muscle-plates of two adjacent radials. But even this character appears to be absent in the remarkable genus *Erisocrinus* from the Upper Carboniferous of America, which has a calyx unusually like that of *Encrinus;* and also in *Stemmatocrinus* from the Russian Carboniferous, which is still more like *Encrinus* in the structure of the arms.

Some forms have a special anal plate between two of the primary radials. This is the

[1] See woodcut, fig. 9 on p. 183.

case in *Belemnocrinus*, and has been thought to afford the only point of difference between it and the cup of the recent *Rhizocrinus*; though the structure of the stem is entirely different in the two types. More commonly, however, there is a considerable development of plates in the anal interradius, and the corresponding basal plate, together with the two radials that rest upon it, differ from their fellows in size and shape. There is, however, one Neocrinoid, the aberrant *Thaumatocrinus* (Pl. LVI. figs. 1–5), which has the symmetry of its calyx disturbed by the presence in the anal interradius of a jointed appendage, somewhat similar to that of *Reteocrinus* from the Trenton group of America, and of *Taxocrinus, Onychocrinus*, &c. But there is no other modification of the plates, the five basals, the lowest interradials, and the radials being all equal and similar to their fellows. Even in Palæocrinoids which have the radials closely united all round, and the general contour of the calyx perfectly regular, a want of symmetry is indicated by the inequality in the numbers of basal and radial plates. This is the case, for example, in *Eucalyptocrinus*, which has five radials but only four basals.

In all Neocrinoids (with the possible exception of the doubtful *Comaster*) the basals are pierced by interradial canals or grooves, which lodge the cords proceeding from the angles of the chambered organ. These cords fork and pass on into the radials, where they occupy the more or less double axial canals (Pl. VIIb. fig. 2, *ai*; Pl. XXIV. figs. 7–9; Pl. LVIII. figs. 1–3—*ai*, *ar*). These axial canals open on the distal faces of the radials in the centre of the transverse articular ridge, and are thence continued into the rays and arms (Pl. III. figs. 1, 3–15; Pl. Vb. fig. 1, A; Pl. Vc. fig. 2, A, figs. 3, 7, 8, 10, *a*; Pl. VIIa. figs. 15–23; Pl. VIIb. figs. 1, 5–8, A; Pl. VIIIa. figs. 5, 7, 8, A; Pl. X. figs. 1–4, 6–8, 17, 18; Pls. XII., XXI., LXII.). Chapman, who has recently attempted a classification of Crinoids,[1] appears to imagine that *Marsupites* and *Uintacrinus* have imperforate radials; for he places them both in his Division 1, "Emedullata," which he characterises as follows, "Calyx and arm-plates without internal canals." I know nothing about the calyx-plates of *Uintacrinus;* but the central canal of the third brachial is shown in Schlüter's figure;[2] while the perforation of the radials of *Marsupites* was mentioned by Miller,[3] and has been figured by many later writers.

The presence of a transverse ridge on the articular faces of the radials indicates that they were united to the second radials by muscles and ligaments, just as the successive arm-joints are. This is invariably the case in all Neocrinoids except *Guettardicrinus*, which has the plates suturally united, and possibly also in *Uintacrinus*. I have pointed out already that there was a fully developed muscular joint between the two lowest radials of many Palæocrinoids such as *Platycrinus* and some, if not all, species of *Cyathocrinus;* and though the arms of *Platycrinus* are pierced by axial canals, it is placed among the "Emedullata" by Chapman.

[1] A Classification of Crinoids, read before the Royal Society of Canada, May 26, 1882.
[2] *Op. cit.*, Taf. iv. fig. 4. [3] *Op. cit.*, p. 138.

None of the Neocrinoids, however, have permanently imperforate radials as so many Palæocrinoids have, the latter group remaining in anembryonic condition as stated already.

In by far the larger number of Neocrinoids which have divided rays, the axillary is the third of the primary radials. The only exceptions are *Metacrinus* and *Plicatocrinus*. In the former genus (Pl. XXXIX. fig. 1; Pl. XLVI.) the first and the axillary radials are primitively separated by from three to six joints, some of which afterwards become united by syzygy; while in *Plicatocrinus* there appear to be only two radials altogether, the first and the axillary. Zittel[1] describes three, it is true, or rather two radials and an axillary brachial; but he speaks of the "innig verschmolzenen Plättchen der unteren Zone' as quite small, and I am strongly inclined to suspect that they represent basals rather than first radials. For what he calls the second radials seem to me to be the first or calyx radials. They are the large trapezoidal plates forming the greater part of the calyx, and united to the lower series by suture; and such a mode of union of the two lower radials occurs in no other Neocrinoid except *Guettardicrinus*.

The position of the axillary joint in those Palæocrinoids which have divided rays is by no means so fixed as in the younger types, for the first radials themselves may be axilliary as in *Allagecrinus;* while in *Poteriocrinus radiatus* the axillary is the sixth joint beyond the first radial, as in some species of *Metacrinus* (Pls. XLIV., XLVI., XLVII.–L.); and in other genera its position may be anywhere between these two extremes. This is in fact the only important character which distinguishes the Palæozoic *Erisocrinus*, *Philocrinus*, and *Stemmatocrinus* from the well known Triassic genus *Encrinus*. *Erisocrinus* has distinct under-basals like those of *Encrinus*, though relatively larger; but in *Stemmatocrinus*, according to Wachsmuth and Springer,[2] these plates are represented by a flat disk, which is undivided, regularly pentagonal, and extends considerably beyond the periphery of the column. Trautschold[3] appears to take the same view of *Stemmatocrinus*. Tempting as it may be, owing to the way in which it would increase the resemblance between these types and *Encrinus*, I feel somewhat loth to accept it. For the plate in question appears to me to be much more truly represented by the central pentagonal piece on which the basals of *Cupressocrinus* rest; this is larger than the stem-joints beneath it, and is obviously what Schultze[4] calls it, viz., "Eine fünfseitige, aus der Erweiterung des obersten Säulengliedes gebildete Platte." Unfortunately we are not acquainted with the mode of development of the under-basals, as they occur in no recent Crinoid; but the analogy of the development of the other calyx-plates indicates that they are primitively five separate plates, like their homologues in the apical system of Ophiurids and Starfishes; and a theory which would homologise them with a plate that first appears as a simple ring, seems to me to run counter to all true

[1] Ueber Plicatocrinus, *loc. cit.*, pp. 107, 108.

[2] Revision, part i. p. 141.

[3] Einige Crinoideen und andere Thierreste des jüngeren Bergkalks im Gouvernment Moskau, *Bull. Soc. Imp. des Nat. Moscou*, 1867, p. 28.

[4] *Op. cit.*, p. 15, Taf. ii. figs. 1 *a*, 6 *a*.

notions of morphology. I freely admit the functional analogy of the under-basals of *Encrinus*, *Erisocrinus*, &c., with the central plate of *Cupressocrinus* or *Stemmatocrinus*; but until the apparently simple nature of the latter shall have been proved to be really due to the disappearance of sutures, as in the basal ring of *Bathycrinus*, *Rhizocrinus*, and *Agassizocrinus*, I think that we must regard it as a top stem-joint, corresponding to what de Loriol calls the "article basal" in *Apiocrinus* and *Millericrinus*.

Encrinus is remarkable as being the only Neocrinoid with ten (or twenty) arms of biserial joints, which increases its resemblance to *Stemmatocrinus*. There are, however, some species (*Encrinus gracilis*) with ten uniserial arms, as in the other Neocrinoids and in *Erisocrinus* so far as yet known. This is also the case in de Koninck's genus *Philocrinus* from the Carboniferous strata of the Punjaub.[1] But the basals seem to be much higher and the cup generally deeper than in either *Erisocrinus* or *Stemmatocrinus*. The structure of the lower part of the cup was unfortunately obscured in de Koninck's specimen, so that the presence of under-basals is still doubtful.

Wachsmuth and Springer point out that the absence of any anal plates in *Erisocrinus* and *Stemmatocrinus*, and the want of any knowledge of their ventral side render it doubtful "whether they belong to the Cyathocrinidæ, or even to the Palæocrinoidea; and if it had not been for their marked resemblance to *Eupachycrinus*, in which a ventral tube has been observed, and that both were representatives of the same geological age, living under the very same conditions, we should have felt strongly disposed to place the whole genus with *Encrinus*, with which it has, indeed, both in body and arms, the closest affinities."[2] They think the number of radials to be not of material, or, at most, "only of generic importance; but in *Encrinus* the aboral side of the body, or the plates which in all Cyathocrinidæ constitute the calyx, form almost a flat disk—at least do not extend beyond the basal plane—and this is the only distinction which can be discovered between the two forms in the fossil state. This, however, may involve important structural modification in the internal anatomy of the animal, and probably shut out *Encrinus* entirely from the Palæocrinoidea."

Our knowledge of the anatomy of recent Crinoids, however, does not favour this supposition. There is very much less difference between the calices of *Encrinus* and *Erisocrinus* than between that of *Antedon eschrichti* with high radials and a narrow but deep central funnel, and the low flattened calyx of any *Actinometra*. But the only difference exhibited by the ventral sides of these two types is that the mouth is central in the *Antedon* and excentric in *Actinometra*. I can therefore see no reason for supposing that *Erisocrinus* had a solid inflexible vault built up of the so-called oral plates, like that of the Cyathocrinidæ, with which family it, as well as *Stemmatocrinus*, is placed

[1] Description of some Fossils from India, discovered by Dr. A. Fleming of Edinburgh, *Quart. Journ. Geol. Soc.*, vol. xix. p. 4, pl. ii. fig. 5.

[2] Revision, part i. p. 142.

by Wachsmuth and Springer on account of its resemblance to *Eupachycrinus*. No such vault has been found in this type, but only a small "ventral tube" which rests on a series of three anal plates and has been traced to the height of the fourth or fifth arm-plate, where it is composed of small, very delicate, hexagonal plates. But these anal plates are absent in *Erisocrinus* as in *Encrinus*, and since a ventral tube or sac like that of *Cyathocrinus* is always found associated with a system of anal plates, the lowest of which is intercalated between two radials, it seems rash to postulate its presence in the symmetrical *Erisocrinus*.

It should be remembered too that the Liassic *Extracrinus* has a symmetrical calyx with a dicyclic base, *i.e.*, of the same composition as that of *Encrinus* and *Erisocrinus;* while its summit or ventral side was in no way different from that of a recent *Pentacrinus*. I have a strong suspicion that this is also true of many Palæocrinoids, and do not therefore believe that *Erisocrinus* must have had a closed vault because it was a Palæocrinoid. Together with *Encrinus, Philocrinus*, and *Stemmatocrinus* it certainly affords the best transition yet known between the Neocrinoids and Palæocrinoids. For the only point of difference about which we are entitled to speak with certainty is the absence of a second radial in the three older forms, and the constancy of its presence in *Encrinus*, as in most other Neocrinoids. The occurrence of *Encrinus*-like forms in the Carboniferous strata of India, America, Russia, and also Spain (according to C. Barrois) is therefore very interesting.

Some species of *Taxocrinus* and *Heterocrinus* have been thought to bear a superficial resemblance to *Pentacrinus*, owing to the freedom of their rays. But both genera have an asymmetrical calyx with a well marked anal side, and also a variable number of radials, peculiarities which, when occurring together, are very characteristic of the Palæocrinoidea.

Wachsmuth and Springer[1] have pointed out that "another very characteristic distinction between ancient and recent Crinoids is to be found in the comparatively large size and massive body plates in the fossil, contrasted with the diminutive body and very long and highly developed arms of recent types; and the same is even more strikingly true as to Blastoids and Cystideans."

But it is a mistake to suppose, as they do, that while the arms are in progress of growth in the Palæocrinoids, those of the Pentacrinidæ are fully developed; for it is among the Comatulæ that the greatest development of the arms is to be found. Very few Pentacrinidæ, except *Extracrinus, Pentacrinus asterius*, and three or four species of *Metacrinus* have more than fifty arms, a number which is never reached by *Apiocrinus* and *Bourgueticrinus*. In certain species of *Actinometra*, however, the rays may branch six or eight times, and the number of arms exceed one hundred; while in many species both of *Antedon* and *Actinometra*, the number of joints in a single arm is over two hundred, and in rare cases reaches three hundred. Nearly all of these bear functional pinnules, the last of which are sometimes longer than their predecessors.

[1] Revision, part i. p. 6.

In the recent Pentacrinidæ, however, there are never as many as two hundred arm-joints, and several of the outermost are entirely devoid of functional pinnules, having nothing but mere stumps in their place, without any ambulacral plates at the edges of their ventral grooves (Pls. XXXVIII., XL., XLII.–XLIV., XLVIII., XLIX.). Nearly one-third of the length of the arm of a *Pentacrinus* or *Metacrinus* may be in this undeveloped condition, which is never met with among the Comatulæ.

In almost all Neocrinoids the articular facets on the first radials occupy the whole width of their distal faces, so that the lowest parts of the rays, whether divided or not, are of nearly the same width as the radial plates which bear them. In many Palæocrinoids, however, such as *Platycrinus*, the articular facet of the first radial simply occupies the middle of its distal edge, so that the lowest parts of the rays are quite small compared with the calyx. This is the case among the Neocrinoids in *Hyocrinus* (Pl. VI.), *Plicatocrinus*, and to a less extent also in *Marsupites;* while it is very characteristic of the young stages of the Pentacrinoid larva of *Comatula*. But the occurrence of this feature is far more general among the Palæocrinoids than in the later forms.

Except in some species of *Encrinus*, the arms of a Neocrinoid are invariably uniserial, *i.e.*, composed of a single series of joints which are placed end to end, and bear pinnules alternately on opposite sides. The arms of the earlier Palæocrinoids were also composed of single joints; but in all the three principal divisions of the group the composition of the arms changed from a single to a double row in the Upper Silurian period. If this is to be considered as an advance in development, then all the Post-Triassic Crinoids are in this respect permanent larval forms. According to Wachsmuth and Springer's description of *Mariacrinus*, the double joint arrangement is brought about by the coalescence of two contiguous arms, an approach to which may perhaps be found in the flattening of the sides of the lower parts of the arms in many Pentacrinidæ and Comatulæ, and in *Holopus* (Pl. Va, fig. 3; Pl. XV. fig. 2; Pl. XVI. fig. 1; Pl. XXX. fig. 1). But this is merely superficial, and the alternate arrangement of the pinnules is unchanged, which is far from being the case in Palæocrinoids with biserial arms. Other Palæocrinoids, such as the Ichthyocrinidæ and some Cyathocrinidæ, seem to have had no pinnules at all, though the arms branched freely.

It will be apparent from what has been said above that except in one or two points, *e.g.*, the symmetry of the calyx, the differences between the so-called Tessellata and Articulata are not so great as has been sometimes imagined. But there is one other structural character of great importance, to which attention has been especially drawn of late by Messrs. Wachsmuth and Springer as distinguishing the two groups. I refer to the condition of the mouth and of the oral surface generally.

The American palæontologists[1] define the cup of a Palæocrinoid as "closed on the

[1] Revision, part i. p. 30.

ventral or oral side by a more or less solid integument, without external food-grooves or oral aperture;" though they imply that the mouth may not have been internal in some cases.[1] In recent Crinoids, however, the mouth and food-grooves are external, though capable of being closed by plates, and the name "Stomatocrinoidea" was consequently suggested for them by Wachsmuth and Springer.

Reference has already been made to the gradual removal of the orals which surround the tentacular vestibule of the larva, from the radial plates; and also to the separation of these orals from one another so as to open the tentacular vestibule to the exterior and expose the mouth in the centre of its floor. In *Holopus*, *Hyocrinus*, and *Thaumatocrinus* the orals persist as large triangular plates which cover up and protect the peristome (Pl. III. fig. 2; Pl. VI. figs. 1–4; Pl. LVI. fig. 5). They are only removed to a short distance from the radials, scarcely at all in fact, in *Holopus*. In *Rhizocrinus* they are relatively much smaller; while they disappear altogether in the Pentacrinidæ and remaining Comatulæ (except *Thaumatocrinus*), so that the mouth is directly exposed to the exterior (Pl. LV.).

In all the recent Crinoids the food-grooves of the disk are perfectly open, like those of the arms, *i.e.*, they are never closed in any other way than by the folding down over them of the plates at their sides (Pl. XVII. fig. 6; Pl. XXVI. figs. 1, 2; Pl. XXX. fig. 2; Pl. XXXIX. fig. 2; Pl. LV.). But in many Palæocrinoids such as *Actinocrinus*, these food-grooves themselves were concealed beneath a vault or dome of rigid heavy plates; so that the mouth towards which they converged was truly subtegminal. The nature of this dome is a point of very considerable importance with reference to the relationship of the Neocrinoids and Palæocrinoids.

Wachsmuth[2] thinks that it "cannot in the remotest degree be homologised" with the ventral side of the Neocrinoids. "The solid dome forms, as I think I have proved, a continuation of the radial and interradial series of the dorsal side, and serves merely as a covering and protection for the organs underneath. It is in every sense of the word aboral, and forms a part of the abactinal system[3] [while the actinal system], which being already reduced in the Pentacrinidæ and Comatulæ to a narrow tentacle furrow, recedes in Palæozoic Crinoids one step farther and disappears within the solid walls of the body. The actinal system here consists externally only of the arm furrows, whence it continues underneath the vault. These Crinoids, therefore, are evidently of lower development and belong to an inferior type. . . . The Palæozoic Crinoids, embracing therein all true Crinoids in which the actinal side is closed, represent the young stage of growth of the living types." Elsewhere Wachsmuth[4] speaks of the ventral covering of *Actinocrinus*

[1] Revision, part i. p. 6.

[2] *Amer. Journ. Sci. and Arts*, vol. xiv. p. 190.

[3] The words enclosed in brackets were unfortunately omitted in the original, thereby confusing the author's meaning not a little.

[4] Revision, part ii. p. 14.

and its allies as forming "a free arch which braces the entire oral side of the body without the aid of oral plates."

The use of the term "aboral" as applied to the vault is somewhat unfortunate, for it actually does cover in the mouth; while the plates of the opposite or dorsal side of the body have generally been called aboral by writers on Echinoderm morphology. Wachsmuth himself applies this expression to the plates of the cup up to the level of the arms. In like manner he gives the name "apical dome plates"[1] to "a system of plates in the vault which occupy a position analogous to that of the apical plates of the calyx;" viz., a central plate, with a proximal ring of interradial, and a distal ring of radial plates disposed regularly around it. These must be carefully distinguished from the dorsocentral, basals, and radials, which are the apical plates of the calyx; and, as mentioned above, have definite homologues in the apical system of Urchins and Stellerids. [See Appendix, Note A.]

The suggestion of Wachsmuth and Goette that the Palæocrinoids represent a comparatively early stage in Crinoid ontogeny, before the opening of the tentacular vestibule to the exterior, has been very generally accepted. But it must be borne in mind that though the Palæocrinoids may be considered as permanent larval forms with respect to the closure of the actinal side, yet that in other respects they have developed to a far greater extent than any Neocrinoid. The solid vault of an *Actinocrinus* is a structure *sui generis*, unless, as I believe, its proximal ring of interradial plates is represented by the orals of a Neocrinoid. The extraordinary development of arms or of other appendages which we find in forms like *Callicrinus*, *Pterotocrinus*, *Ollacrinus*, *Eucalyptocrinus*, *Crotalocrinus*, &c., is entirely without a parallel among the more regular and symmetrical Neocrinoidea. We must be careful therefore not to make too much of the one or two embryonic characters presented by the Palæocrinoids, as compared with the facts of their great complexity of structure and immense variety of form.

The simplest type of summit to be met with in any Palæocrinoid is that presented by the Devonian genus *Haplocrinus*, which remains permanently in the condition of a very early larva. For the orals, together with certain upward processes of the radials on which they rest, form a closed pyramid just as in an early Pentacrinoid. There are five openings which lead in beneath this oral pyramid and correspond to the points of attachment of the arms; but its apex is completely closed so that there is no external mouth. The lines of suture between its component plates are generally marked by deep grooves which descend from the closed apex to end below at the radial openings. Wachsmuth and Springer call them compartments for the reception of the arms, while they have been described by Zittel[2] as "nach unten geschlossene, nach oben offene Ambulacralfurchen."

This appears to me to be a mistake, and I do not see any reason for supposing that these orals were ever covered in by plates as he elsewhere suggests.

[1] Revision, part i. p. 28.

[2] Palæontologie, p. 347.

If, as Zittel supposes, the ambulacra of the arms were continued past the radial openings and up the steep sides of the oral pyramid, which is closed at the apex, how did they reach the peristome underneath? Did not food-grooves and the subjacent ambulacral structures pass in beneath the oral pyramid at the radial openings, so as to reach the mouth and the vascular and nervous rings around it, just as they must have done beneath the dome of *Actinocrinus*? It appears to me that *Haplocrinus* is permanently in the condition of a Pentacrinoid larva with a closed tentacular vestibule; though in other respects, such as the attachment of the brachial plates by muscles[1] and ligaments above a perforated articular ridge, it presents an advance upon that condition. There is an important feature in the structure of the oral pyramid of *Haplocrinus* which has long escaped notice. Goldfuss[2] long ago described the furrows which mark the sutures between the oral plates, and went on to say "wo diese im Scheitelpuncte zusammenstossen, steht ein rundes Knöpfchen." This is quite clearly shown in his figures, but has attracted no attention from subsequent workers. Lately, however, it has been discovered by Mr. Wachsmuth that there is really a small but distinct plate in this position, occupying the central portion of the summit of the oral pyramid. I am indebted to him both for the opportunity of verifying this observation by examination of his specimen of *Haplocrinus mespiliformis*, and for permission to make use of it in this chapter. This plate is one of considerable importance in its morphological relations. In accordance with the views which I have expressed elsewhere,[3] I believe it to be the representative on the actinal side, or left larval antimer, of the dorsocentral plate which is developed in the centre of the right antimer or abactinal side of Urchins, Stellerids, and Crinoids. I have reason to think that this belief has been adopted by Mr. Wachsmuth not only so far as regards *Haplocrinus* and *Symbathocrinus*, but also for the Platycrinidæ and Actinocrinidæ as well. The orals, as shown by Goette,[4] are the actinal representatives of the basals, being developed spirally around the left vaso-peritoneal tube; while the basals, like the so-called genitals of Urchins and Starfishes, appear in a spiral around the right peritoneal tube. They are disposed interradially, and rest in most cases directly against the dorsocentral; while the orals of *Haplocrinus*, also interradial, rest against the single plate discovered by Wachsmuth, which occupies a central position in the summit, immediately above the peristome, as in so many other Palæocrinoids. I propose to call it the "orocentral."

In the remarkable series of specimens of *Allagecrinus*[5] which have been obtained by the collectors of the Geological Survey of Scotland, the smallest and least developed individuals are in the same morphological condition as *Haplocrinus*, or perhaps even in a more primitive one. The calyx is covered by a round dome of oral plates, which rests

[1] Schultze, Echinodermen des Eifler Kalkes, p. 105.
[2] Petrefacta Germaniæ, Theil. i. p. 214, tab. lxiv. figs. 6*b*, 6*c*.
[3] *Quart. Journ. Micr. Sci.*, 1879, vol. xix., N. S., pp. 179–182; 1884, vol. xxiv. p. 14.
[4] *Loc. cit.*, p. 621.
[5] *Ann. and Mag. Nat. Hist.*, 1881, ser. 5, vol. vii., pp. 282–289.

on the summit of the radial pentagon. Although I have examined a large number of individuals with especial reference to this point, I have not succeeded in finding any trace of an orocentral plate. At the centre of the upper edge of each radial is a minute opening which leads inwards beneath the dome; but there is no arm-facet corresponding to this opening, still less a first brachial resting on the radial as is often found in *Haplocrinus*. The dome is rounded and smooth, and not marked by any radiating furrows like that of *Haplocrinus*, so that the ambulacra must have passed in beneath it over the upper edges of the radials. Why then may we not suppose them to have done the same in *Haplocrinus*?

In the larger specimens of *Allagecrinus* the orals are smaller relatively to the radials, the upper edges of which have minute semicircular arm-facets; while the ambulacral openings above these facets are relatively larger. In the next stage of development the orals are still more reduced relatively to the radials, which bear distinct articular facets for the attachment of the brachials by means of muscles and ligaments around a perforated transverse ridge, just as in any recent Crinoid. Even in these individuals, however, which must have had fairly well developed arms, the relatively small oral pyramid is still closed, just as in the early Pentacrinoid and in *Haplocrinus*.

Another form which remained permanently in the same condition, but had even better developed arms, was *Symbathocrinus*. For the so-called "apical dome plates"[1] (which I regard as orals) rest directly upon the upper edges of the articular faces of the radials; and they form a closed pyramid or dome with five radial or ambulacral openings, one between every two orals. While, however, the orals of *Allagecrinus* form the whole dome, its centre is occupied in *Symbathocrinus* by a single orocentral plate, around which the orals are grouped, just as in *Haplocrinus*. For the knowledge of this important fact and permission to make use of it here, I am again indebted to Mr. Wachsmuth, who will shortly describe it more fully. He is, I believe, disposed to agree with me in considering the central plate as an orocentral, and the circle of apical dome plates around it as orals, homologous with those of *Haplocrinus*, *Allagecrinus*, and the Pentacrinoid.

This dome of oral plates in *Symbathocrinus* is only very rarely found preserved; but its discovery by Wachsmuth is of extreme importance in many ways; while it indicates that although no dome has been met with in the two largest specimens of *Allagecrinus*, its absence may be only accidental and not natural.

On the other hand, there is the possibility that the dome of oral plates in *Allagecrinus* became separated from the radials by the growth of intervening perisome, just as the orals are in all recent Crinoids except *Holopus*; though whether they also separated from one another so as to open the mouth to the exterior, must remain undecided for the present. It is of course possible that they may have separated from one another without being removed from close proximity to the radials, just as is the case in *Holopus*; and

[1] Revision, part ii. pp. 17, 67.

they might then have been lost after the decay of the perisome uniting them. Those of *Holopus* were retained in the dry specimen which was figured by Pourtalès,[1] and subsequently by Sir Wyville Thomson; and the condition of the Palæozoic *Coccocrinus* seems to me to be entirely explained by that of the recent *Holopus*.

Wachsmuth and Springer[2] describe it as follows:—"In well preserved specimens of *Coccocrinus*, the vault is constructed of five large oral plates, which rest upon five interradial pieces. The oral plates are not in contact laterally, but leave five slits, which in the fossil have no floor nor covering, and leave an open space in the centre." They are strikingly similar to the orals of the recent *Hyocrinus* (Pl. VI. figs. 1–4), as has been pointed out by Zittel; and the resemblance to the orals of *Holopus* (Pl. III. fig. 2) is still greater, as the latter rest directly against the calyx plates, which is not the case in *Hyocrinus*. In both the recent forms and also in *Thaumatocrinus* (Pl. LVI. fig. 5) the clefts between the triangular oral plates are open and uncovered, as in *Coccocrinus*. Schultze[3] follows Roemer in thinking that these slits do not penetrate into the cavity of the calyx; but that they were hollows for the reception of the arm bases, as in *Eucalyptocrinus*. But Wachsmuth, having examined Schultze's specimens, states distinctly that these grooves have no floor. He says in the Revision (part ii. p. 17) that "the similarity to *Hyocrinus* is probably merely superficial, as the lateral grooves in *Coccocrinus* were evidently (*why?*) closed by additional plates as in other Platycrinidæ, while they are open in *Hyocrinus*." Again "it is evident that the central space and open furrows were covered in the animal as in similar genera." The oral plates "do not join laterally nor in the centre, but leave a median space and lateral slits, which in perfect specimens were doubtless closed, the one by the apical dome plates and the slits by small marginal pieces." . . . . "In *Coccocrinus* a covering of the ambulacral groove has not yet been observed, but, judging from the fissure between the oral plates, it probably rested just upon their edges, and formed an intermediate link between the vault structure of the Cyathocrinidæ and Platycrinidæ."[4]

When Wachsmuth wrote the passages which have been quoted above, he held, like Zittel and myself, that the five large triangular plates which rest on the primary interradials of the calyx are homologous with the orals of recent Crinoids. He has since, however, come to the conclusion that "*Coccocrinus* had externally no oral plates, its so-called orals are secondary interradials, and mouth and food-grooves were covered by supra-oral plates" (Extract from Letter). I must confess that I greatly doubt the existence of this additional covering in *Coccocrinus*, which seems to Wachsmuth so evident; for I find it difficult to believe that the "Scheitelstücke," as Schultze called them, are not oral plates like those of the Neocrinoids. It is of course possible that their resemblance to the orals of *Holopus*, *Hyocrinus*, and *Thaumatocrinus* is simply an

[1] Hassler Crinoids, pl. x. fig. 9.
[2] Revision, part ii. pp. 17, 58.
[3] *Op. cit.*, p. 89.
[4] Revision, part ii. pp. 17, 30, 58, 59.

accidental one, and that I am inclined to attach too much importance to it; and in that case I should certainly agree with Wachsmuth in calling them secondary interradials. One point, however, is worth notice. The orals of *Thaumatocrinus*, like those of *Hyocrinus* (Pl. VI. figs. 1–4; Pl. LVI. fig. 5), are only separated from the calyx plates by the thin band of perisome round the edge of the disk, which develops in the equatorial zone of the larva, concurrently with the increase in the diameter of the cup. These genera are thus in the condition of the advanced Pentacrinoid of *Antedon rosacea*, the oral circlet of which, owing to the increase in the size of the visceral mass, becomes detached from the summit of the primary radials; and the space between the two series is filled by the perisome of the equatorial zone, which separates the right and left larval antimers.

In the early stages of *Hyocrinus*, before this process had taken place, the orals would rest directly against the upper edges of the radials, as they do in *Holopus* (Pl. III. fig. 2), but in *Thaumatocrinus* they must rest against the primary interradial plates. They would thus be in precisely the same relative position as the "Scheitelstücke" of *Coccocrinus;* but I do not think that when a young *Thaumatocrinus* is found in this condition Wachsmuth will call the oral plates "secondary interradials"; though he uses this term for the plates of *Coccocrinus* which I, like Allman and Zittel, consider as representing the orals of Neocrinoids, including *Thaumatocrinus*.

If then the "Scheitelstücke" of *Coccocrinus* be oral plates, there are strong morphological reasons against the supposition that the ambulacra which pass in between them were closed by small marginal pieces, *i.e.*, by covering plates like those which occur so frequently on the arms and pinnules of many Neocrinoids (Pl. Vc. figs. 8–10; Pl. XIII. figs. 15, 16; Pl. XVII. figs. 2–4, 7–9) and Palæocrinoids, and on the summit of *Cyathocrinus*. Why should we invoke the existence of a "vault" over the orals of *Coccocrinus*, simply because it is a Palæocrinoid? There is nothing of the kind in the recent *Holopus* which dates back to the Chalk; while the allied genera *Cotylecrinus*, *Eudesicrinus*, and *Eugeniacrinus* are almost as old as the Mesozoic period. In no recent Crinoid, nor in the Pentacrinoid larvæ of those species which have covering plates to the ambulacra do these plates rest upon the edges of the orals. They commence at the margin of the peristome which is covered in by the orals, but there are none bordering the edges of the grooves between these plates.

It is partly, I believe, owing to his feeling the force of this objection that Mr. Wachsmuth prefers to consider the "Scheitelstücke" of *Coccocrinus* as secondary interradials, rather than as orals. When he has found a specimen showing the small pieces at their edges, I shall probably agree with him. But for the present I am inclined to lay more stress on the resemblance of the "Scheitelstücke" of *Coccocrinus* to the orals of Neocrinoids; although, according to Wachsmuth,[1] "this resemblance is probably merely

[1] Revision, part ii. p. 17.

superficial, as the lateral grooves in *Coccocrinus* were evidently closed by additional plates as in other Platycrinidæ, while they are open" in Neocrinoids. But the existence of these additional plates does not seem to me so evident as it does to him. He attempts to support his position by reference to a "close resemblance" between the summit of *Coccocrinus* and that of the Cyathocrinidæ, which he describes as follows:[1]—"Calyx surmounted by five large oral plates, with a central opening between them, and forming at their sutures five shallow ambulacral grooves converging toward the centre. Central opening covered by the apical dome plates, and the five grooves arched over by two rows of small immovable pieces alternately arranged."

The so-called oral plates of this description are those which Wachsmuth had previously called "consolidating plates," thinking them to be homologous with the plates of the same name in *Cupressocrinus*. He subsequently came to the conclusion, as did Zittel about the same time, that they are homologous with the orals of the Pentacrinoid; and he therefore also spoke of them by this name. He likewise regarded the deltoid pieces of the Blastoids in the same way. I must plead guilty to having also adopted this view, which had much to recommend it at first sight. I did not do so, however, without considerable hesitation, on account of one morphological difficulty which it involved. For the ambulacra would then pass *over* and not *between* the edges of the oral plates, which would bear a double row of marginal pieces or covering plates continuous with those on the arm-grooves. This, as pointed out above, is contrary to the nature of the oral plates of Neocrinoids; and the result of the correspondence on the subject between Mr. Wachsmuth and myself is that we can no longer regard either the deltoid pieces of the Blastoids or "the principal vault pieces" of *Cyathocrinus* (as Meek and Worthen call them) as representing the orals of Neocrinoids. I am now disposed to consider that "*Cyathocrinus* and the Blastoids have but one interradial plate, which reaches up to the peristome." Mr. Wachsmuth's first criticism of this statement was that "it expresses exactly my views."

I believe, however, that his views have since undergone some further modifications, as he will himself explain in the forthcoming part (iii.) of his Revision.

But the question of the structural resemblance between *Coccocrinus* and *Cyathocrinus* is independent of the nomenclature of the plates. It is one of some importance in its bearing on the belief of Zittel and myself on the condition of the mouth in the former type and its relation to that of Neocrinoids. In the first place, as pointed out by Wachsmuth and Springer,[2] *Cyathocrinus* has only one plate resting "against the incurved upper margins of the radials;" while in *Coccocrinus* the primary interradial bears a triangular plate, which they now consider as a second interradial, though formerly regarding it as an oral plate, as do Zittel and myself. The central opening in *Cyathocrinus* is much larger than in *Coccocrinus*, owing to the truncation of the

[1] Revision, part i. p. 68.

[2] *Ibid.*, part ii. p. 17.

principal vault pieces or interradials, as they were also called by Meek and Worthen.[1] The grooves which converge upon it are not like those of *Coccocrinus* "which have no floor," [2] but they are formed at the sutures of the interradials, *i.e.*, the apposed edges of these plates are bevelled away so as to form a groove with the suture in the middle of its floor.

According to Wachsmuth and Springer,[3] the central space "in perfect specimens is completely covered by the apical dome plates. The food-groove and ambulacral canal are also arched over solidly by two rows of alternate plates which connect with the movable covering of the arm furrow." The existence of these marginal alternating plates has yet to be proved in *Coccocrinus*, and until this has been done, the resemblance between this type and *Cyathocrinus* does not seem to me to be very "close," for while the arm-grooves of *Cyathocrinus* are continued towards the peristome over the united edges of the interradials, this is by no means the case in *Coccocrinus*; and there is no groove on the ventral disk at all, any more than there is in *Holopus*, or in any young Crinoid before the separation of the orals and radials by the expansion of the equatorial zone. The fact that the principal vault pieces of *Coccocrinus* are not united laterally, as is the case in *Cyathocrinus*, seems to me to be one of very considerable morphological importance. It must of course be remembered, as Wachsmuth has pointed out in other cases, that the absence of a covering to the central space and its radial clefts in the fossil *Coccocrinus* is no proof that it was not present during life as in *Cyathocrinus*. But the two genera are not in the same morphological condition, and all that we *know* about *Coccocrinus* goes to indicate its resemblance to *Holopus* with open slits between the orals and an uncovered mouth. Wachsmuth,[4] however, states that he has "yet to discover a single palæozoic genus in which a special oral aperture has been identified, or in which the existence of a solid vault has been disproved, or cannot be traced by analogy." I believe, on the contrary, that the special oral aperture is to be found in *Coccocrinus* as in *Holopus*, and that it is pushing analogy too far to assert the existence of an as yet undiscovered vault in this genus.

If then, as I believe, there was an unobstructed mouth in *Coccocrinus* as in *Holopus*, I cannot agree with Zittel's association of this type with *Haplocrinus*, which had a closed oral pyramid.

Wachsmuth and Springer[5] place *Coccocrinus* near *Platycrinus*. "The two genera are identical in the construction of the calyx, and the summit really forms the only distinction between them." To this point I shall return. *Coccocrinus*, like the recent *Holopus*, seems to me to be permanently in the condition of a Crinoid larva in which the orals have not yet moved away from the radials, though separated from one another.

Haplocrinus and *Symbathocrinus* are permanently in the condition of an unopened

[1] Palæontology of Illinois, vol. v. pl. ix. fig. 13.
[2] Revision, part ii. p. 58.
[3] Revision, part i. p. 84.
[4] *Amer. Journ. Sci. and Arts*, vol. xiv. p. 190.
[5] Revision, part ii. p. 58.

Pentacrinoid; while the apical dome plates in the Cyathocrinidæ, to which reference has been made already, as covering the central opening of the summit, do not reach anything like either the size or the regularity of arrangement that is to be found in the plates which have been described by Wachsmuth under the same name in other Palæocrinoids. In the Blastoids, with the exception of *Eleacrinus*, they are generally small and irregular as in *Cyathocrinus*; but in the Platycrinidæ, Actinocrinidæ, and Rhodocrinidæ they form a group of seven plates in the centre of the vault. The central plate is surrounded by six others, four of which are of equal size, while the remaining two are smaller. They are separated by the anal tube, and correspond to a single plate, just as *Eleacrinus* has the deltoid piece on the anal side divided into two parts, which are separated by the anal opening and its supporting plate.

Professor Allman[1] pointed out long ago that many Palæocrinoids have a group of plates in the centre of the vault, which is nothing but a more or less extensive development of the simple oral system of the young *Comatula*. This pregnant suggestion refers to the seven apical dome plates of *Platycrinus* and *Actinocrinus* which correspond as I believe to the orocentral and five orals of *Haplocrinus* and *Symbathocrinus*, having been developed like them on the left larval antimer; while the rest of the vault in *Actinocrinus* is a further extension of this oral system, which is unrepresented in the Neocrinoids. Thus then, though *Platycrinus* and *Actinocrinus* are in the condition of having the tentacular vestibule and peristome permanently closed, just as in *Haplocrinus*, yet they have undergone an immense development upon this condition as a basis. The tentacular vestibule in the Pentacrinoid larva is merely the peristome concealed beneath the oral pyramid; but in *Actinocrinus* it is greatly enlarged so as to take in the whole surface of the disk; and the ambulacra passed over this surface towards the central mouth from the periphery of the disk, where they entered the dome from the arms through the well known arm-openings or ambulacral openings. These gave passage not only to the ambulacra proper or food-grooves, but also to extensions of the body-cavity, and to the radiating trunks of the nervous, blood-vascular, and water-vascular systems. All these last lay between the body-cavity and the food-grooves, and converged towards their respective circum-oral centres. The upper surface of internal casts of the vault of *Actinocrinus* is marked by bifurcating ridges which indicate the position of the food-grooves radiating from a central peristome, just as in the disk of a recent *Antedon*, as has been pointed out by Wachsmuth.[2] Traces of these ambulacra are often found in the interior of the vault. In many cases they were covered in by a double row of alternating plates just like those of the arms, with which they were continuous at the arm-openings. They were floored by a double row of plates, and so formed tunnels beneath the vault, but closed independently of it by the covering plates on their upper surface.

[1] On a Prebrachial stage in the development of Comatula, *Trans. Roy. Soc. Edin.*, 1863, vol. xxiii. pp. 245–251.
[2] *Amer. Journ. Sci. and Arts*, vol. xiv. p. 119.

I suspect that these tunnels lodged not only the food-grooves, but also the nerves, blood-vessels, and water-vessels; for no recent Crinoid has any calcareous structure between the epithelium of the food-groove and the under surface of the water-vessel. But there is often a tolerably definite plating which extends inwards from the side plates toward the median line of the ambulacrum, beneath the water-vessel (Pl. LIV. fig 11; Pl. LVII. fig. 4, *sub*; Pl. LXII.); and I suspect therefore that the lower row of plates flooring the ambulacral tunnels may be of this nature. Possibly, however, they should be regarded as subambulacral plates better defined in character than those of recent Crinoids, though I am inclined to doubt this, owing to their alternate arrangement. Wachsmuth has discovered that the proximal ends of these ambulacral tunnels are connected by a circular vessel which encloses more or less of the upper part of the convoluted digestive organ. The lower part of this structure, with its floor of minute interlocking plates, was obviously the water-vascular ring; and the five interradial openings in its floor were referred to by myself in 1879[1] as indicating the position of the water-tubes which depend from the water-vascular ring into the cœlom, and serve to admit water into the ambulacral system, a view which has been adopted by Zittel. *Rhizocrinus lofotensis* has only one water-tube in each interradius, which seems also to be the case in *Actinocrinus verneuilianus*.

Besides the ambulacral skeleton, we also find in the Palæocrinoids representatives of the anambulacral plates of *Pentacrinus* and *Comatula*. In describing some natural casts of the visceral mass of *Actinocrinus*, Messrs. Wachsmuth and Springer[2] say "the interpalmar fields are composed of a soft skin, but although this is more or less encrusted with limestone particles, which sometimes almost look like vault pieces, they have no affinities with the plates of the vault;" while in some specimens of the Actinocrinidæ[3] "almost the entire test is lined with a delicate calcareous plexus or network. This lining is not in contact with the test directly, but connected with it by small partitions, producing innumerable little chambers, which communicate with each other and with the visceral cavity. . . . . The structure extends but little below the region of the second radials, leaves passages at the arm-openings, and toward the vault "reaches to a place near the median portion of the ray, leaving at the centre an open space in the test which is occupied by the central vault piece." This open space, lying beneath the central one of the apical dome plates and uniting the five ambulacra, was evidently the peristomial area like that of recent Crinoids (Pl. XVII. fig. 10; Pl. XXVI. figs. 1, 2; Pl. XXXIX. fig. 2; Pl. L. fig. 2; Pl. LV.); while the calcareous network within the vault is divided by the ambulacra into five interpalmar fields. It corresponds to the limestone particles on the surface of the internal casts, and represents the anambulacral plates developed in the perisome of recent Crinoids.

These important observations go to show the complete resemblance between the

[1] *Quart. Journ. Micr. Sci.*, 1879, vol. xix., N. S., p. 185.
[2] Revision, part ii. p. 31.
[3] Revision, part ii. p. 26.

ventral perisome of a recent Crinoid and the upper surface of the body beneath the vault of an *Actinocrinus*. Both had plated ambulacra and anambulacral plates. The admitted resemblance of the interpalmar anambulacral plates of the Actinocrinite to "vault pieces" is another point in favour of the view which I take of the so-called vault in the Ichthyocrinidæ. I believe this to be a true "ventral disk" similar to that of *Pentacrinus*, and not in any way homologous to the solid vault of the Actinocrinidæ.

In describing the Palæocrinoids, Wachsmuth uses "vault," "summit," and "ventral disk" as synonymous terms.[1] This is somewhat unfortunate, as tending to lead to confusion.

The expression "oral disk" or "ventral disk" is universally used to denote the upper surface of the visceral mass of a Crinoid, *i.e.*, that in which the mouth is placed, with the food-grooves radiating outwards from the peristomial area around it. Wachsmuth speaks of this surface as the "soft or ventral peristome" (perisome ?), and says that it cannot in the remotest degree be homologised with the solid vault of the Palæocrinoids. Hence his occasional reference to this vault as a ventral disk is a little confusing; and his use of the word "interpalmar" is equally so.

He sometimes employs it[2] to denote the interradial spaces between the ambulacral ridges on the upper surface of the casts of *Actinocrinus*. This surface corresponds to the ventral disk of *Pentacrinus;* and "interpalmar" is here used by Wachsmuth in the same sense as it was by Müller, *i.e.*, for the "interradialen Felder zwischen den Tentakelrinnen." When therefore he employs "interpalmar" to denote the interradial plates of the vault,[3] its meaning is entirely different; for the vault was a dome of solid plates, completely concealing the mouth, food-grooves, and interpalmar areas on the ventral disk.

The vault and ventral disk are, to my mind, entirely distinct structures. The former is necessarily formed of closely-fitting solid plates; while the latter, lying beneath it, may be bare as in many Comatulæ, or more or less completely plated as in *Actinocrinus* and the Pentacrinidæ. But no recent Crinoid, not even *Thaumatocrinus*, has anything like a dome or vault rising above a ventral disk. Numerous specimens are known with the covering plates at the sides of the food-grooves closed over them so as to convert them into tunnels (Pl. XVII. fig. 6; Pl. LV. figs. 3–7). But this was also the case beneath the vault of *Actinocrinus*. Sometimes, indeed, the plates of the disk may be so closely set that the opening of the mouth, which may be large in other specimens, is nearly or quite concealed, as in the so-called recent Cystidean *Hyponome* (Pl. LIV. fig. 10; Pl. LV. figs. 4, 5, 7). But this is in no way comparable to the embryonic closure of the mouth before the separation of the valves of the oral pyramid. It is only in this and similar cases that I admit the presence of a vault, dome, or tegmen calycis. This structure reaches its fullest development in the Actinocrinidæ and Platycrinidæ; though *Haplo-*

[1] *Amer. Journ. Sci. and Arts*, vol. xiv. pp. 181, 185. Revision, part i. pp. 5, 32, 54; part ii. p. 53.
[2] Revision, part ii. pp. 26, 27, 31. [3] Revision, part ii. pp. 64, 107.

crinus and *Symbathocrinus* had a more or less rudimentary one, consisting of an orocentral and five oral plates only, without any radial extensions.

The vault of the Actinocrinidæ is much more complex than in the Platycrinidæ and Rhodocrinidæ; but its relations to the internal organs are so much better understood than in these families that it may well be considered first. This is more especially the case, as certain parts of Wachsmuth's generalised description of the vault of these three families apply to the Actinocrinidæ only, and occasionally even to some genera only.

It has been stated above that the vault of the Actinocrinidæ formed a solid roof or dome over the oral surface of the visceral mass, which was covered with ambulacral and anambulacral plates like the disk of a *Pentacrinus*. Wachsmuth has discovered that whatever the size and extent of the vault the apical dome plates are invariably present. "They consist of a central piece, occupying a position directly above the oral centre, which in this family is quite uniformly the centre of the disk. It is surrounded by six proximal plates, interradial in position, of which four are large and equal, and two smaller. The four large plates are placed above the four regular interradial spaces respectively; the two smaller ones, which are equivalent to and take the place of one large plate, are directed posteriorly, being separated from each other by anal plates or the proboscis. . . . There are other vault pieces occupying a radial position which are either in contact with those just described, or, as is more frequently the case, separated from them by a belt of small pieces. Their number varies considerably among species, and depends upon the number of primary arms, without reference to the number of bifurcations after they become free. They increase in proportion to the number of primary arms, in the same manner and on the same principle as the plates of the calyx, each order of radials has its corresponding plates in the vault. . . . There are also interradial plates represented in the summit, occupying intermediate spaces between the radials, but their arrangement is very irregular and their number variable."[1] The number of these interradial plates depends greatly upon the age of the individual, and is therefore very uncertain; but as a general rule the number of summit plates increases regularly with that of the primary arms, just as that of the calyx plates does. The above statements, though true enough for the Actinocrinidæ, are scarcely so accurate as regards the Platycrinidæ.

This discovery of Wachsmuth's respecting the distribution of the radial dome plates in the Actinocrinidæ is of enormous importance for the proper comprehension of the true nature of the vault of a Palæocrinoid; and, taken in connection with the embryological work of Goette, throws much light on the morphology of the Crinoids, and indeed of Echinoderms generally.

By far the most interesting of these summit plates are the "apical dome plates" in the centre, which Wachsmuth says are relatively larger in young specimens. This and other considerations led him to point out their resemblance to the apical plates of the aboral

[1] Revision, part ii. pp. 14, 15.

side, which are of equally fundamental importance in the calyx.[1] "The six proximal plates surrounding the central piece represent the basals or genitals, and the radial dome plates the radials or oculars. The centre piece may perhaps be compared with the underbasals, or the subanal plate of the Echini." In an earlier statement of these homologies[2] no "perhaps" was used respecting the nature of the central actinal plate; and I have pointed out that while accepting Wachsmuth's[3] comparison to the full extent, as regards the radial and interradial plates in the centre of the dome, I cannot follow him in his recognition of the dorsocentral, nor of its fellow, the orocentral, as homologous with under-basals.[4] His views, as expressed in the Revision, are essentially those of Lovèn, formerly also held by Agassiz, when allowance is made for the different systems of nomenclature used by him and by them. I have endeavoured to show elsewhere that there cannot be a true homology between a dorsocentral plate which is single from the first, and the five under-basals of a dicyclic Crinoid. These are by no means universally present, as one would expect them to be, did they correspond to the dorsocentral of the Echinozoa, which is such a prominent object in the larva of an Urchin, Starfish, or Ophiurid; while representatives of the under-basals of Crinoids are actually present, together with a dorsocentral plate, in some Starfishes and Ophiurids.[4] The dorsocentral is developed at the distal end of the right peritoneal tube; and as there is a plate occupying the same position in the Crinoid larva, viz., the future terminal plate at the base of the stem, it is only natural to regard the two as homologous, as pointed out by myself in 1878. I am glad to find that this view has commended itself to Dr. Lütken[5] and also to Sladen; and I understand from Mr. Wachsmuth that he is now in accordance with me respecting the homologies of the central vault piece, considering it as representing the dorsocentral of Echinoderms generally, and not the under-basals of those Crinoids in which these plates occur. [See Appendix, Note A.] His view of the proximal interradial dome plates of the Actinocrinidæ, however, is entirely different from that here advocated, and will shortly be published *in extenso* by himself; while he has also abandoned his suggestion that the interradial dome plates in the Actinocrinidæ, Platycrinidæ, and Rhodocrinidæ are "the homologues of the oral plates, which are here broken up, and represented by five plates instead of one.[6] This relieves me from the necessity of discussing it here, as I had otherwise intended to do.

My own idea of the homologies of the calyx and dome plates of Crinoids is expressed in Table VII.

[1] Revision, part ii. pp. 15, 16.

[2] *Amer. Journ. Sci. and Arts*, vol. xiv. p. 189.

[3] *Quart. Journ. Micr. Sci.*, 1878, N. S., vol. xviii. pp. 369–371; 1879, vol. xix. pp. 181, 182; 1882, vol. xxii. pp. 377, 378.

[4] See Sladen, On the Homologies of the Primary Larval Plates in the Test of Brachiate Echinoderms, *Quart. Journ. Micr. Sci.*, 1884, vol. xxiv., N. S., pp. 32–36; also, The Apical System of Ophiurids, *ibid.*, pp. 3–15.

[5] Dyreriget, en Haand- og Lærebog til Brug ved høiere Læreanstalter, Kjøbenhavn, 1882, p. 597.

[6] Revision, part ii. p. 17.

I regard the inner ring of interradial dome plates (proximals) in the Actinocrinidæ and Platycrinidæ as representing the orals of a Neocrinoid, or of *Symbathocrinus*, *Haplocrinus*, and the young *Allagecrinus*. This view was first suggested in 1879,[1] and all that has since been written on the subject by Wachsmuth and Springer, who have not discussed it in any way, has only served to make me more confident of its truth.

In the first place, Wachsmuth himself has recognised from palæontological evidence the close similarity between the proximal interradial plates of the actinal and abactinal systems respectively. Those of the abactinal system are the basals, which in *Actinocrinus* and *Cyathocrinus* "develop very early in the young, and attain almost their full

TABLE VII.—*Showing the Mutual Homologies of the Principal Plates in the Actinal and Abactinal Systems of Echinodermata.*

		Urchins.	Ophiurids.		Crinoids.		
		Abactinal.	Abactinal.	Actinal.	Abactinal.	Actinal.	
						Symbathocrinus.	*Actinocrinus.*
1.	Central plate.	Dorsocentral.	Dorsocentral.	...	Terminal plate at base of larval stem.	Orocentral.	Orocentral.
2.	First series, radial.	...	Under-basals, (variable).	...	Under-basals, (variable).	...	...
3.	Second series, interradial.	Genitals.	Basals.	Mouth-shields.	Basals.	Orals.	Proximal dome plates.
4.	Third series, radial.	Oculars.	Radials.	...	Primary calyx radials.	...	Primary dome radials.
	...	...	...	...	Orders of calyx radials.	...	Orders of dome radials.
	...	...	...	...	Calyx interradials.	...	Dome interradials.

No representatives of the under-basals have been detected as yet in the apical system of an Urchin, nor in the oral (or actinal) system of any Echinoderm.

size when even the first radials are comparatively much smaller."[2] This is also true of the basals of recent Comatulæ, and of the orals as well; while in like manner the proximal dome plates of *Actinocrinus* are relatively largest in young individuals.

Goette's observations show the complete homology between the basals and orals, both being developed spirally, the former round the right, and the latter round the left peritoneal tube. The basals are primitively next to the abactinal centre in Urchins and Stellerids, and are only removed from it in the Crinoid by the growing stem; while the orals are next the actinal centre, no plate being developed there, however, in the recent

[1] *Quart. Journ. Micr. Sci.*, 1879, vol. xix., N. S., p. 179.

[2] Revision, part i. p. 20.

Crinoid. Did it appear, it would only be in the way, and have to undergo resorption to a greater or less extent, just as the dorsocentral of many Urchins is more or less completely resorbed after the appearance of the anus.

As regards the recent Crinoids, therefore, the embryological evidence clearly indicates that the basals of the abactinal system are represented in the actinal system by the orals. The former are within the ring of radials and next to the dorsocentral; and it seems therefore only natural to regard the six proximal interradial plates surrounding the central piece (orocentral) in the vault of a Palæocrinoid as representing oral plates.

Wachsmuth admits that Zittel was right in regarding the interradial plates which form the dome of *Haplocrinus* as representing the orals of Neocrinoids; and he takes the same view of the interradial plates in the dome of *Symbathocrinus*. I should have thought therefore that he would have given a similar interpretation of the summit plates in *Platycrinus* and *Culicocrinus*. Those of the latter genus were described by Müller as follows:—"Der Scheitel besteht aus 5 Tafeln, welche dicht an einander schliessen durch Nähte und anderseits bis an die Arme und die Interradialia reichen, sie stehen übrigens interradial, so dass jedes Interradiale zu einem der funf Scheitelstücke stimmt. Der Mund (*cf.* anus) befindet sich seitlich in einem Interradius zwischen dem Interradiale und entsprechenden Scheitelstuck. Auf jeder der 5 Scheiteltafeln erhebt sich ein kurzer Dorn."[1] Wachsmuth calls these "Scheitelstücke" of Müller's the proximal vault pieces, and suggests that "probably his largest plate includes four plates, the spiniferous central vault piece, the two proximal vault pieces, and a small anal plate between them. The four large proximal vault pieces, each crowned with a spine, are no doubt correctly represented. Those few plates occupy the greater part of the summit, leaving but little space for the radial dome plates, which as yet are unknown."[2]

I think myself that this suggestion is totally unnecessary; for the five summit plates appear to me to form a closed oral pyramid in which the plate on the anal side is somewhat wider than its fellows, but not divided into two as in the Actinocrinidæ and Platycrinidæ.

Culicocrinus has the proximal dome plates resting against the calyx interradials, just as the orals do in *Coccocrinus*. But no distal ring of radial dome plates is known in this genus. This advance in complexity is presented by certain forms of *Platycrinus* from the Carboniferous limestone, both at Burlington and at Bolland. Müller gave some figures of the latter under the name of *Platycrinus ventricosus*, Goldfuss, which is certainly wrong;[3] and I have examined several specimens in the British Museum collection which are in this comparatively primitive condition. The proximal dome plates rest directly against the calyx interradials,[4] that on the posterior side being represented by two small plates with the anus between them; while there is a more or less tubercular

[1] *Verhl. d. Naturhist. Verein. d. preuss. Rheinl.*, Bd. xii., Jahrg. 1855, p. 23.

[2] Revision, part ii. p. 62.

[3] Bau des Pentacrinus, *loc. cit.*, Taf. vi. figs. 1*a*, 1*b*.

[4] It is only just to Mr. Wachsmuth for me to state here that he was the first to direct my attention to the fact that Platycrinidæ exist with the proximal dome plates resting directly against the calyx interradials, two individuals in this

ring of radial dome plates outside them. These proximal dome plates thus correspond exactly to the orals of *Symbathocrinus* and *Haplocrinus*, covering in the peristome and resting against the calyx plates, which in the *Platycrinus* are the interradials, and not the upper edges of the radials, as in the simpler forms.

The disk underneath was therefore larger, owing to the greater width of the cup, and an additional ring of plates, the radial dome plates, was necessary to protect it. Wachsmuth admits the homology of these with the calyx radials, which are separated from the dorsocentral by the basals; and I cannot therefore see what other view can be taken of the proximal dome plates which immediately surround the orocentral, than to regard them as orals, *i.e.*, as the actinal representatives of the basals, like the corresponding plates in *Symbathocrinus*. If this be admitted, it follows that the proximal dome plates of all Platycrinidæ, Actinocrinidæ, and Rhodocrinidæ are also homologous with the orals of Neocrinoids.

In most Platycrinidæ the primary radial dome plates are succeeded by others of a different character, which do not precisely correspond to the various orders of calyx radials, as will be mentioned later; but in the Actinocrinidæ the correspondence between the actinal and abactinal sides is very complete. Thus in *Stelidiocrinus capitulum*[1] the orocentral and six proximals (orals, *mihi*) take up almost three quarters of the summit, the remainder of which is occupied by a single anal, and three radials to each ray, the two outer ones being very small. All gradations can be traced from this condition into the complex vault of a *Strotocrinus*, which is described as follows by Messrs. Wachsmuth and Springer:—

"The disk is paved by many hundreds of small minute pieces which decrease in size towards the arms, and which at the outer points of the rays become almost microscopic. The apical plates are larger, and are separated from each other, but not otherwise distinguished from the other plates, and hence are not easily identified."[2] In young individuals, however, there are comparatively fewer summit plates than in the adult. "The apical and principal radial pieces are larger than the intervening interradial plates which, exceptionally in this genus, attain by age the same size as the apical and radial pieces."[3] The same kind of complexity and irregularity as in *Strotocrinus*, though not quite so well marked, is characteristic of the summit of *Mariacrinus*, *Periechocrinus*, and *Physetocrinus*, and also of *Marsupiocrinus*, which is placed next to *Platycrinus* by Wachsmuth and Springer. In *Mariacrinus* "the vault is composed of very minute irregular pieces without definite arrangement, even the apical dome plates are obscure."[4] In *Physetocrinus* only the proximal dome plates are distinguishable;

condition having been found by him in the Burlington limestone. He was kind enough to send me one of these for examination; and it was only after seeing it that I was struck by Müller's figures, to which I had previously not paid very much attention. I have since examined several similar specimens from the Bolland limestone.

[1] Revision, part ii. p. 99.
[2] *Ibid.*, part ii. p. 159.
[3] *Amer. Journ. Sci. and Arts*, vol. xiv. p. 188.
[4] Revision, part ii. p. 116.

while in *Periechocrinus* the vault is composed "of small irregularly arranged smooth pieces, among which the apical dome plates are indistinctly represented."[1]

All these genera, therefore, resemble *Strotocrinus*, and from the evidence of that genus we are entitled to believe that the apical dome plates would be relatively more prominent at earlier stages of development. Now this is exactly the case with the orals of recent Crinoids, which at first surround the whole of the upper surface of the larval body; but eventually may be altogether resorbed or gradually reduced in comparison with their fellows, the basals, as in *Rhizocrinus* (Pl. X. figs. 2, 3, 7).

Thus then I believe the oral or actinal system forming the vault of *Actinocrinus* to have been developed on the left larval antimer, in exactly the same way as the apical or abactinal system is developed on the right; but the oral system, instead of being limited to five oral plates as in Neocrinoids, reached a very extensive development, so that in its completest form it presents such a parallel to the apical or abactinal system as is to be met with in no other Crinoid, much less in any other Echinoderm.

The greater variability in the development of the proximal plates, and their occasional separation by smaller intercalated pieces, resembles the extreme irregularity of the apical system of an Ophiurid, as compared with that of a Crinoid or Urchin.[2] The interradial plates of the former (or basals) have important relations to the chambered organ. Those of the Urchin (genitals) are often connected with the genital ducts; and the radial plates in the same way have important functions in both groups. In the disk of an Ophiurid, however, neither interradial nor radial plates are of any functional importance; and we find accordingly that their state of development differs very considerably even in allied species. Much the same is the case in the dome of the Actinocrinidæ, where the plates are not in any way specially related to internal organs, though serving to protect them.

Wachsmuth totally denies that there is any homology between the solid vault of a Palæocrinoid and the ventral or oral disk of a recent form. So far as the Actinocrinidæ are concerned, I entirely concur in this opinion, except as regards those Neocrinoids, such as *Hyocrinus*, *Thaumatocrinus*, and *Holopus*, which have persistent orals. For I believe that representatives of these plates exist in the vault of all Palæocrinoids, whether simple or complex, although they are sometimes very greatly reduced; and I cannot therefore agree with Zittel[3] in considering them as entirely absent in the vault of Actinocrinidæ, Platycrinidæ, Melocrinidæ, Rhodocrinidæ, &c.

The Cyathocrinidæ and the Blastoids seem to resemble *Strotocrinus* and *Periechocrinus* in the small size and want of definite arrangement of the apical dome plates. Neither in Wachsmuth's famous specimen of *Cyathocrinus malvaceus*, nor in any of the Cyathocrinidæ figured in Angelin's Iconographia can any definite arrangement of the

[1] Revision, part ii. p. 131.
[2] *Quart. Journ. Micr. Sci.*, 1884, vol. xxiv., N. S., pp. 4–14.
[3] Palæontologie, p. 331.

ummit plates be made out. One of the figures[1] of the "perisoma ventrale" in *Cyathocrinus alutaceus* shows a central plate with seven others round it; while in the other, three large plates meet in the centre of the vault, but no one of them could be considered as an orocentral. The same may be said of the vault of *Cyathocrinus lævis* represented in tab. xxvi. fig. 3*b*.

As regards the Blastoids I have never been able to trace any definite grouping of the summit plates, although I have examined a very large number of picked specimens of *Pentremites*, *Granatocrinus*, *Schizoblastus*, and *Orophocrinus*.

In *Eleacrinus*, however, the case is different. There are comparatively fewer plates over the peristome, and they certainly often do have a definite grouping, five surrounding a central one as was first described by Roemer.[2]

No more need be said about the Blastoids, as their ambulacra are in many ways abnormal, though they have strong points of resemblance to those of the Cyathocrinidæ. This family is one of special interest, for Wachsmuth[3] says that in the structure of their vault they "bear closer resemblance to the recent Crinoids than almost any other group, and seem to hold an intermediate position between modern and Palæozoic types. If the alternating plates, covering the furrows, could be turned back at the vault by the animal, as the Saumplatten of the arms, then the food-groove of these Crinoids was open throughout, as in recent forms." It is possible therefore that although the mouth and peristome were subtegminal, *i.e.*, covered in by the apical dome plates, yet the food-grooves of the body may have been just as much external as those of the arms, and in no way different from those on the disk of a *Pentacrinus*. As regards the Cyathocrinidæ, therefore, one of the characters on which Wachsmuth relies as separating the Palæocrinoids from the Neocrinoids would then have no existence, *i.e.*, the absence of external food-grooves. I am not prepared to assert, however, nor indeed is Wachsmuth, that these alternating plates in the radial areas of the vault of *Cyathocrinus* were movable, like the covering plates of the disk in recent Crinoids. For it seems to me quite possible that the closure of the peristome may have been continued outwards on to the very short calyx-ambulacra, which would then first become open to the exterior at the bases of the arms. But I have no question as to the homology between the radial vault pieces in *Cyathocrinus*, and the covering plates of recent Crinoids, each set passing continuously into the covering plates of the brachial ambulacra.

According to Wachsmuth's descriptions of the vault of the Actinocrinidæ the arrangement of the radial dome plates is the same as that of the radial calyx plates; and he is obliged to admit[4] that the alternating radial dome plates which he finds in *Cyathocrinus* are "not so readily distinguished as in the Platycrinidæ and forms with free rays, in

[1] *Op. cit.*, tab. xxiii. figs. 10*b*, 11.

[2] Monographie der fossilen Crinoideenfamile der Blastoideen und der Gattung Pentatremites im besondern, *Archiv f. Naturgesch.*, Jahrg. xvii., Bd. i. pp. 377, 378, Taf. v. figs. 1*b*, 1*c*.

[3] *Amer. Journ. Sci. and Arts*, vol. xiv. p. 184.

[4] Revision, part ii. p. 30.

which they are well marked in the extended parts. In the recent Crinoids the alternate plates are represented by the 'Saumplättchen,' which, however, instead of forming a part of a solid vault, are movable, and line the lateral margins of the tentacle furrows."

Now these "Saumplättchen" or covering plates of recent Crinoids are imbedded in the ventral perisome, and Wachsmuth admits that this is represented in the Actinocrinidæ by the interpalmar areas on the upper surface of his internal casts, and in the calcareous network which lines the interior of the vault. He describes how the ambulacra pass outwards from the peristome within the body, and communicate directly with the arm-grooves.

I believe myself that the tubular skeleton beneath the vault, which has thus far been observed only in the Actinocrinidæ,[1] represents the covering of the disk-ambulacra of the recent Crinoids, passing at the arm-openings directly into the ambulacral skeleton of the arms. The following passage[2] seems to imply that Wachsmuth is of the same opinion :— "It is now generally conceded that the tubular canals beneath the vault contain the same organs which in modern Crinoids are exposed on the ventral disk, and like them embrace the food passages and certain other vessels connected with the ambulacral system." If then the tubular skeleton beneath the vault correspond to the covering plates of the disk in recent Crinoids, how can these last be represented by the alternating plates in the dome of the Actinocrinidæ, which, as Wachsmuth himself admits, are not readily distinguishable?

Another difficulty also presents itself in connection with Wachsmuth's views respecting these alternating plates of the ambulacra. Those on the calyx he considers as vault pieces; those on the arms as representing the covering plates of recent Crinoids. But in another place he tries to prove that they are rudimentary pinnules, a question which has been already discussed.[3]

Now it is obvious that the plates covering one end of an ambulacrum cannot be vault pieces, while those at the other end are covering plates *or* rudimentary pinnules—they cannot be both. It appears to me tolerably certain that the whole series of *regular* alternating plates, calicular and brachial, represent the covering plates on the disk and arms of recent Crinoids; but I will not venture to assert that they were invariably movable on the vault and free rays, so as to expose the food-grooves to the exterior.

The condition of *Gissocrinus* seems to me to confirm this view very strongly, and also to emphasise the difference between *Cyathocrinus* and *Coccocrinus*, to which I have alluded above.

The composition of the calyx in *Gissocrinus* is the same as in *Cyathocrinus*, but the lowest arm-joints instead of resting on the outer edges of the radials, lie upon their ventral surface, and extend downwards towards the peristome over the sutures between

[1] Mr Wachsmuth tells me that he has lately found "tubular canals beneath the vault" both in *Platycrinus* and in some of the *Rhodocrinidæ* (August, 1884).

[2] Revision, part ii. p. 29.

[3] *Ante*, pp. 61–66.

the interradials. Wachsmuth[1] expresses this by saying that "the arms are recumbent upon the vault. There are five oral (*cf.* interradial) plates, upon the sutures between which, and raised above the general level, the arm-joints are imbedded, being covered by small alternating plates like the free arms." Here then we have a further development of the abnormal condition presented by *Cyathocrinus* and the Blastoids. For not only ambulacral plates, but arm-joints themselves, extend over the sutures between the interradials towards the opening at the centre of the summit. The two rows of alternating plates which cover in the furrows clearly represent the plates arching over the grooves between the interradials of *Cyathocrinus;* but it is equally clear that they are the covering plates of ambulacra which are borne by the arm-joints. This is very evident in some of Angelin's figures[2] of the brachial ambulacra, which may be advantageously compared with those of the ambulacra in the Comatulidæ and Pentacrinidæ (Pl. XIII. fig. 16; Pl. XVII. figs. 2, 6, 7; Pl. XXVII. figs. 4, 5, 11, 12; Pl. XLVII. figs. 10–13; Pl. LIV. figs. 4, 7, 8; Pl. LV. figs. 3–7).

The two rows of alternating plates in the dome of the Platycrinidæ have a close resemblance to those on the vault of *Cyathocrinus*, and I have a strong suspicion that they are of the same character, and not radial dome plates homologous with the calyx radials, like those in the Actinocrinidæ. Wachsmuth appears to have been in much doubt about their nature, and to have had considerable difficulty in making up his mind. For he has described them in very different terms at different times. The following general description was written by him as applying to both Platycrinidæ and Actinocrinidæ, as well as to the Rhodocrinidæ. Speaking of the radial dome plates,[3] he says "as a general rule, the summit plates increase in proportion to the number of primary arms of a species in the same manner and on the same principle as the plates of the dorsal side. Every radial from the third radial upward has a corresponding plate on the ventral side, and additional interbrachial plates between corresponding brachial plates above the arms."

This description, although true of most of the Actinocrinidæ, does not appear to hold good for any typical Platycrinoid, as far as can be judged from Wachsmuth's accounts of the vault structure in the different genera of the family. The vault of *Coccocrinus* has been sufficiently discussed already. That of *Cordylocrinus* is not known. The radial dome plates of *Culicocrinus* are as yet unknown, and but little room is left for them, as the apical dome plates occupy the greater part of the summit. In the next genus, *Marsupiocrinus*, however, the condition of the vault is entirely different. Wachsmuth and Springer[4] describe it as follows: "vault low, hemispherical, composed of a larger number of plates than usually found in this family. These are generally formed into

[1] Revision, part i. p. 91.

[2] *Op. cit.*, tab. xxvii. figs. 1*e*–1*g*; tab. xxix. figs. 75*d*, 76*a*.

[3] *Amer. Journ. Sci. and Arts*, vol. xiv. p. 187. This passage appears again with a slight alteration in the Revision, part ii. p. 15.

[4] Revision, part ii. p. 64.

narrow ridges, which bifurcate twice within the body.[1] Interradial dome plates larger than the radial, apical plates not prominent and identified with difficulty, interpalmar spaces paved with small pieces." Figures of the vault of *Marsupiocrinus radiatus* and *Marsupiocrinus depressus* are given by Angelin.[2] The former shows a few larger plates in the centre which may be the apical dome plates; but in the other figure none of the plates in the centre are specially large; so that it is possible that *Marsupiocrinus* may resemble many recent Crinoids in the total resorption of the orals, causing the proximal ends of the interpalmar areas to be thickly studded with plates which tend to obscure the position of the mouth (Pl. XVII. fig. 6; Pl. LIV. fig. 10; Pl. LV. figs. 4, 5, 7). From the numerous bifurcating ridges formed by the radial dome plates, I cannot help suspecting that these plates are not true vault pieces as in the Actinocrinidæ, but the covering plates of closed ambulacral tunnels. They have a very different arrangement from the various series of radials on the abactinal side, which should not be the case if they belong to the vault, *i.e.*, to the oral system. It will be remembered that Wachsmuth has compared them to covering plates, while regarding them as true vault pieces; and he speaks of the interradial areas between them as "interpalmar," a term which is inapplicable to true vault pieces, though I think he has used it correctly in the case of *Marsupiocrinus*. For I have a very strong impression that the so-called vault of this genus is really the strongly plated ventral perisome, in the centre of which the remains of the orals (apical dome plates) are perhaps to be found. I cannot see any such essential difference between it and the plated disk of *Pentacrinus wyville-thomsoni* or of many *Antedons* (Pl. XVII. fig. 6; Pl. LV.) as would lead to the supposition that the homologue of the latter is to be sought for beneath the vault of *Marsupiocrinus*. At the same time I have no intention of asserting the presence of an external mouth and open food-grooves on the calyx of this genus. For although these are present in the apparently similar disks of the recent forms, I think it not impossible that the tentacular vestibule over the peristome of *Marsupiocrinus* may never have opened to the exterior, and that the covering plates of the food-grooves proceeding from it may have been immovably closed down over them. They were thus converted into tunnels, but were still "external," in the sense of not being covered by a "tegmen," as those were which formed the tubular skeleton beneath the vault of the Actinocrinidæ. In the recent *Hyocrinus*, which has many Palæocrinoid affinities, the food-grooves pass from the oral to the ambulacral system in the body before they reach the arms (Pl. VI. figs. 1–4); and I see no reason why they should not have done the same in some of the Platycrinidæ, the family which is supposed by Wachsmuth to represent an incompletely developed condition of the Actinocrinidæ.

In *Platycrinus*, *Hexacrinus*, and *Talarocrinus* the structure of the vault is

[1] They bifurcate considerably more than "twice" in *Marsupiocrinus radiatus*.

[2] *Op. cit.*, tab. x. figs. 16, 21.

very different from that of *Marsupiocrinus*, and is more like that of the Actinocrinoid; but the apical dome plates (orocentral and orals) take up the greater part of the summit, so that the radial dome plates are but little developed, and do not follow the arrangement of the calyx plates, as described by Wachsmuth in *Strotocrinus* and other Actinocrinidæ. Those of *Platycrinus* extend on to the free rays as a double row of alternating plates. Wachsmuth says nothing about the covering of the arms; but there are two rows of alternating plates on the pinnules, and these are obviously covering plates. It is difficult to believe that the food-grooves of the arms were unprotected, when those of the pinnules borne by them were bordered by covering plates; and if these were present on the arms, what was their relation to the two alternating rows of radial dome plates upon the free rays? Should not the alternating plates of the free rays, arms, and pinnules be considered as parts of one system, just as the small covering plates of the pinnules of Pentacrinidæ are traceable into the larger ones on the arms, and through them into those of the disk (Pl. XVII. fig. 7; Pl. XXXIII. figs. 3, 4, 6; Pl. XLI. figs. 4, 13; Pl. LIV. fig. 7)?

The free rays of *Platycrinus* find a parallel in many recent Crinoids. In *Platycrinus burlingtonensis* the first division borne on the radial axillary consists of two joints only, of which the second is axillary. "One face of this bears an arm directly, while the other supports two pieces in direct succession, the second of which is an axillary piece and gives origin to two arms."[1] This arrangement would be described in a *Pentacrinus* or *Comatula* as consisting of two distichal and two palmar joints, the latter only occurring on the inner pair of every two secondary arms; so that the arm formula would be 1, 2, 2, 1, instead of 2, 1, 1, 2 as in *Pentacrinus alternicirrus*, &c. (Pl. XXV.). Many Comatulidæ and Pentacrinidæ have more than two joints in the distichal and palmar series, and these do not belong to the arms proper, but support radiating extensions of the disk, which is often much incised and heavily plated (Pl. L. fig. 2; Pl. LV. figs. 3–7). In the dry state the plates remain attached to the distichal and palmar joints, and cover them in by a kind of vault (Pl. XXXIII. fig. 6), just as the radial dome plates cover in the free rays of *Platycrinus*, though on a much smaller scale. As in the case of *Cyathocrinus* and *Marsupiocrinus*, therefore, I believe that these alternating radial dome plates of *Platycrinus* are really covering plates of the ambulacra, though permanently closed down, and terminating against the primary radial plates of the dome outside the ring of proximals.

These primary radials are sometimes well developed, as in *Talarocrinus* and *Pterotocrinus*. In the former[2] "the first radial vault-piece is spiniferous in most species, the succeeding plates small and nodose, arranged longitudinally in rows, forming together regular arches over the ambulacral passages within the body." The vault of *Pterotocrinus* seems to have had a closer resemblance to that of *Actinocrinus* than is the case in most

[1] Palæontology of Illinois, vol. v. p. 453, pl. iii. fig. 6.

[2] Revision, part ii. p. 86.

Platycrinidæ, for it had radial dome plates of the first, second, and even occasionally of the third order.

Apart from this aberrant type, however, the radial regions in the vault of the Platycrinidæ seem to have consisted of a double row of small, more or less alternating plates. Their arrangement does not by any means correspond regularly to that of the radial calyx plates, as would appear from Wachsmuth's generalised description of the vault[1] in the Sphæroidocrinidæ, *i.e.*, Platycrinidæ, Actinocrinidæ, and Rhodocrinidæ. In fact the greater part of this description holds good for the Actinocrinidæ only.

The peripheral portion of the vault of *Platycrinus, i.e.*, the zone betweenthe proximal dome plates in the centre and the calyx interradials, is comparatively small; and its interradial spaces are "occupied by three—rarely five—plates, smaller than the central dome plates, and less nodose, but yet comparatively large, and resting upon the interradial of the calyx."[2] This series of four or six interradials, taken all together, doubtless corresponds generally to the single large interradial of *Cyathocrinus*, as was supposed by Wachsmuth when he considered the latter as an oral. I do not mean that the one plate is homologous to the larger number; but only that they all belong to the same system of interradial plates. The position of the alternating dome plates in *Cyathocrinus* and *Platycrinus* would then be very much the same. They rest in the one case between, and in the other upon the interradials, and terminate against the apical dome plates. Wachsmuth says, for example, "in *Platycrinus* the interradial plates thus take exactly the same position as the exposed parts of the oral plates in *Cyathocrinus*, while the covered parts are unrepresented."[3] In this type too the calyx interradials enter into the composition of the summit, just as is the case in *Cyathocrinus*. Thus Wachsmuth says that "the first interradial, which exceptionally in this group is placed almost within the dome regions, is identical with the outer (*i.e.*, primary) interradial plate of *Coccocrinus*,"[4] in which I entirely agree.

He further says, "the vault of the Platycrinidæ differs in several particulars from that of the other Sphæroidocrinidæ, and in these same characters it approaches the Cyathocrinidæ."[5] I do not myself think that the vault of a Platycrinite was exactly of the same nature as that of an Actinocrinite, *i.e.*, that it covered in the whole of the visceral mass and the ambulacra on its upper surface. For if the alternating dome plates represent the covering plates of recent Crinoids, as Wachsmuth suggests, then all the periphery of the dome, outside the apical dome plates (orocentral and orals), must be the real ventral surface of the body, and not a *tegmen calycis* as in *Actinocrinus*. Wachsmuth himself admits that the alternating plates in the dome of *Platycrinus*, like those of *Cyathocrinus*, are represented by the covering plates of recent Crinoids; and also that no tubular skeleton has been discovered beneath the vault of any Palæocrinoid except an Actinocrinite.

[1] *Amer. Journ. Sci. and Arts*, vol. xiv. p. 187; and Revision, part ii. p. 15.
[2] Revision, part ii. pp. 17, 30, 69.
[3] *Ibid.*, part ii. p. 30.
[4] *Ibid.*, part ii. p. 18.
[5] *Ibid.*, part ii. p. 16.

If his first admission be correct, as I believe it to be, one would not of course expect to find a subtegminal ambulacral skeleton in *Platycrinus*.[1]

There is some point on the actinal side of every Crinoid where the food-grooves leave the oral system covering up the peristome in which they originate, and are only closed by the covering plates at their sides.

In the recent *Hyocrinus* this closure takes place on the disk, where the food-grooves come out from under the oral pyramid (Pl. VI. figs. 1–4). In *Symbathocrinus* the oral pyramid was closed by the orocentral plate, and not open as in *Hyocrinus;* while the disk must have been even smaller than in that type, as the orals rest directly on the radials, so that the ambulacra of the arms which were protected by covering plates, commence directly from the sides of the oral pyramid almost as in *Thaumatocrinus* (Pl. LVI. fig. 5). The Bolland *Platycrinus* which was figured by Müller is essentially in the same condition as *Symbathocrinus*, the orals (apical dome plates) resting directly against the plates of the abactinal side, in this case the calyx-interradials; while the oral or actinal system is increased by the development of the radial dome plates corresponding to those in the calyx, which rest directly over the arm-openings and are followed by the ambulacral plates of the free rays.

If the orals of *Thaumatocrinus* formed a closed pyramid resting directly on the interradials, as it must in earlier stages of growth; and if this pyramid were further extended at its base by the development of radial plates in the actinal system, then the ambulacra would start from the periphery of these plates just as the alternating plates of the free rays do in *Platycrinus*.

In other Platycrinidæ the oral system seems to have been still larger, having secondary and tertiary dome-radials; but sooner or later it came into contact with the alternating series of plates which I take to be the skeleton of closed ambulacra, that perhaps only opened to the exterior at the origins of the arms from the free rays. There was a membranous disk, the radial regions of which were traversed by the ciliated food-grooves beneath the ambulacral skeleton above; while the interpalmar regions supported the interradial plates of the vault. Both the ambulacral skeleton and the interradial

[1] By this I mean distinct covering plates such as are found beneath the radial dome plates of the Actinocrinidæ. There must, of course, have been a "tubular passage beneath the vault," the presence of which is indicated on the natural casts from a cherty bed in the Upper Burlington limestone, which have been recently examined by Mr. Wachsmuth. From what he has told me about these internal casts of *Platycrinus* I imagine that they show very much what he has already described in similar siliceous casts of *Actinocrinus*, viz., "elevated rounded ridges, almost like strings overlying the surface"; and his remarks upon these last (*Amer. Journ. Sci. and Arts*, vol. xiv. p. 120) seems to me to be equally applicable to the *Platycrinus*-casts. He says: "The position of the string-like ridges (in case they represent passages as I can hardly doubt) is analogous with that of the *open food-grooves* of recent Crinoids." In *Actinocrinus*, however, he not only found this evidence of passages beneath the vault which lodged the food-grooves; but he also discovered in some specimens preserved in a different way, that these passages were protected by a distinct ambulacral skeleton, itself below the radial dome-plates. I imagine that this subtegminal skeleton, which corresponds to the ambulacral skeleton on the disk of *Pentacrinus* (Pl. XVII. fig. 6) does not exist in *Platycrinus*. For the ambulacral skeleton of this type was largely developed and external, forming the "alternate plates of the dome" (August 1884).

plates were more massive than in recent Crinoids, just as the former were in the Cyathocrinidæ; and I do not think therefore that there was anything within the vault of Platycrinidæ like the tubular skeleton and the network of anambulacral plates that occur in *Actinocrinus*. The greater part of the above argument appears to me to be a mere logical deduction from Wachsmuth's very suggestive remark[1] that the alternate plates in the dome of Platycrinidæ are represented in the recent Crinoids "by the 'Saumplättchen,' which, however, instead of forming a part of a solid vault, are movable, and line the lateral margins of the tentacle furrows."

Although believing that the vault of a Platycrinoid corresponds collectively to the orals, interradials, ambulacral, and anambulacral plates of Neocrinoids, I do not wish to assert that the Platycrinidæ either had an external mouth or open ambulacra on the disk. For I imagine that both were closed as in *Cyathocrinus*, the whole system of plates being much more substantial than in Neocrinoids, and forming part of a solid covering, but not a true vault or *tegmen calycis*.

In the Actinocrinidæ, on the other hand, not only the food-grooves themselves, but also their skeleton of alternating plates, were subtegminal, together of course, with the plated interpalmar areas of the disk. The oral or actinal system of plates does not consist merely of an orocentral with one or two rings of plates round it, which cover in the peristome and the origins of the ambulacra from it. It is so greatly developed as to cover in and conceal the whole ventral surface of the body, *i.e.*, the disk proper. The subtegminal food-grooves passed outwards from the peristome over this upper surface of the disk, and were continued on to the arms through the ambulacral openings round the dome. A primary dome-radial is always present beyond the orals, and may be followed by secondary, tertiary plates, &c. *Stelidiocrinus* has very few dome-radials, but in other types the number becomes very large, in correspondence with the development of different orders of radials in the calyx. Sooner or later, however, the subtegminal food-grooves reached the arm-openings, and the minute plates protecting them were continuous with the skeleton of the brachial ambulacra.

There is one form which is placed by Wachsmuth and Springer among the Actinocrinidæ, but has a vault of very different construction from that of the other members of this family. In fact it somewhat resembles that of *Marsupiocrinus*. I mean *Carpocrinus ornatus* (*Habrocrinus, Angelin*). Wachsmuth describes its radial portions as "covered by two rows of low transversed pieces; interpalmar fields paved by somewhat larger and elongate plates."[2] As pointed out above, the word "interpalmar" denotes the areas between the radiating food-grooves; and its use by Wachsmuth is therefore significant. I cannot resist the suspicion that the double row of low transversed pieces indicates the position of a food-groove; and that the covering plates may have been permanently closed down so as to convert the grooves into tunnels, without the additional

[1] Revision, part ii. p. 30.

[2] *Ibid.*, part ii. p. 106.

help of a tegmen, such as occurs in the Actinocrinidæ. The proximal ends of these tunnels would open into the closed peristomial space beneath the pyramid of apical dome plates or orals. In fact, *Carpocrinus* appears to me to be in the condition of a *Hyocrinus*, with an oral pyramid composed of somewhat smaller plates, but permanently closed, like the ambulacra of the disk. While therefore I am in complete accordance with Wachsmuth respecting the closure of the peristome and calyx-ambulacra in the Cyathocrinidæ, Platycrinidæ, and Actinocrinidæ, I cannot altogether agree with him in denying all homology between the solid vault of a Palæocrinoid and the soft disk of a recent form. For I believe that both in the Cyathocrinidæ and in the Platycrinidæ the plates which form the vault are unusually massive representatives of the ambulacral, anambulacral, and interradial plates which are developed in the perisome of a *Pentacrinus* or *Comatula*.

The Ichthyocrinidæ and some of the doubtful Silurian forms, such as *Reteocrinus* and *Xenocrinus*, appear to me to occupy an intermediate position between the heavily vaulted Platycrinidæ and the more thinly plated recent forms. Some of the Mesozoic species, such as *Extracrinus*, *Apiocrinus*, *Guettardicrinus*, and *Marsupites*, which have comparatively thick plates on the sides and surface of the disk, also help to fill up the gap.

The only genus of Ichthyocrinidæ in which the summit is known at all satisfactorily is *Onychocrinus*. Wachsmuth and Springer describe it as follows:[1]—"Interradials three to twenty, perhaps more in some species; the first one large, resting between the first and second radials; the succeeding ones smaller, rapidly decreasing in size and thickness upward, and having an inward curvature. They are followed by very minute, irregular polygonal plates, which form the interradial portion of the vault. The radial summit areas consist of two rows of somewhat larger plates, alternately arranged, which extend to the ventral covering of the free rays, and probably throughout their full length. In the median portion of the vault there are six rather thin but large apical dome plates." I understand, however, from Mr. Wachsmuth that he is now less inclined to believe in the presence of apical dome plates in the Ichthyocrinidæ; and I will not therefore take their presence as established. If they exist I should call them oral plates, and compare the vault to the disk of a *Hyocrinus* with a closed oral pyramid. But in their absence the vault appears to me so closely to resemble the disk of *Pentacrinus* and *Comatula*, that I cannot question the identity of the two for the merely *a priori* reason of the Ichthyocrinidæ being Palæocrinoids.

The two rows of alternating plates which radiate outwards over the "squamous integument," and extend on to the free rays (*i.e.*, distichal and palmar series), are surely nothing more than the covering plates of the ambulacra, which were perhaps permanently closed as in the Platycrinidæ, or only temporarily so, as in the Neocrinoids; while the small irregular plates which form the interradial portion of the vault, correspond to the

[1] Revision, part i. pp. 53, 54.

anambulacral plates of recent Crinoids (Pl. XVII. fig. 6; Pl. LV.). They pass downwards into the interradials at the sides of the calyx, just as in the recent species and in the Liassic *Extracrinus*.

Wachsmuth stated in 1877[1] that although he had not found the summit of any Ichthyocrinoid perfectly preserved, he felt convinced from what he had observed "that it did not consist of a soft skin." Subsequently, however, he described the ventral disk of the Ichthyocrinidæ[2] as "rarely preserved; composed of a more or less soft or scaly integument, yielding to motion in the body and arms. . . . The interradial areas are sometimes found depressed and in other cases distended, showing that there had been some expansion or contraction of the body-walls due to the mobility of the radial parts, and indicating likewise flexibility in the vault."

Under these circumstances I find it difficult to believe that the ventral disk of the Ichthyocrinidæ did not correspond to the similarly named structure in recent Crinoids, but represents the solid vault of *Actinocrinus*. Were this the case, there must have been another flexible skin inside the "pliant scaly integument," with the food-grooves passing over its upper surface as they do over that of an internal cast of *Actinocrinus*. It is of course impossible that a proof of the existence of such a structure can ever be obtained. But why should its existence be postulated at all, simply because *Ichthyocrinus* is a Palæocrinoid?

According to Wachsmuth and Springer "this family might very appropriately be called the Articulates of the Palæozoic Crinoids, being especially distinguished in most of its species by what seems to be an articulate structure in the whole skeleton."[3] I cannot but believe that they present a similar approximation to Neocrinoids in the structure of their vault, ventral disk, or whatever else it be called.

Any Crinoid with a well-plated disk (Pl. XIII. fig. 1; Pl. XVII. fig. 6; Pl. XXVI. figs. 1, 2; Pl. L. figs. 1, 2; Pl. LV.) appears to me to be a recent *Onychocrinus*. If the summit of this genus was soft, pliant, and flexible, it must have consisted like the ventral disk of a *Pentacrinus* of a perisome formed of connective tissue, with the numerous irregular interradial plates imbedded in it; and I cannot bring myself to believe that the flexible summit was really the "tegmen" overlying another disk, which itself represented the plated ventral perisome of *Pentacrinus*. It is admittedly a direct continuation of the "squamous integument" uniting the rays on the dorsal side. This is "composed of very minute irregular polygonal plates, or by distinct interradial and axillary plates, the former varying in number from one to thirty or more."[4]

Thus *Onychocrinus* has a large first interradial which rests between the first and second radials. "The succeeding ones are smaller, decrease rapidly in size and thickness, and pass gradually into the very minute irregular plates which form the interradial

[1] *Amer. Journ. Sci. and Arts*, vol. xiv. p. 185
[2] Revision, part i. p. 31.
[3] *Ibid.*, part i. p. 31.
[4] *Ibid.*, part i. p. 31.

portion of the vault."[1] I have seen a similar arrangement in well preserved specimens of *Marsupites*, while both d'Orbigny[2] and de Loriol have figured and described the same thing in *Apiocrinus roissyanus*. After stating that there is a considerable amount of variation in the interradial areas, even in the same individual, de Loriol says—"Presque toujours la série commence par une pièce unique, hexagone ou heptagone, qui est la plus grande, et se trouve encastrée entre les premières et les secondes radiales, de chaque côté, reposant sur les troncatures des premières radiales. Au-dessus il y a deux, trois, et même quatre pièces plus petites, irrégulières, polygonales, qui arrivent au niveau des facettes articulaires des troisièmes radiales, une troisième et une quatrième rangée comprennent encore chacune trois ou quatre pièces polygonales plus petites, et occupent l'espace entre les premiers articles brachiaux; elles sont suivies par d'autres rangées de pièces, plus petites encore, qui paraissent concourir à la formation d'une voûte sur la cavité calicinale."[3] De Loriol's enlarged representation of this structure is reproduced in fig 9. Here, surely, there was a "dome" as solid as in any Ichthyocrinoid; but it will scarcely be contended that this dome represents the heavy rigid vault of *Actinocrinus*, rather than the plated ventral perisome of recent Pentacrinidæ and Comatulidæ. The former range back to the earliest Mesozoic times, long anterior to *Apiocrinus*; and the Liassic *Extracrinus* had a vault essentially similar to that of the Apiocrinidæ. But there was no regular calyx-interradial resting upon the upper angles of the first radials. Its place was taken by a number of movable irregular perisomic plates, like those which occur in the same position in *Pentacrinus asterius* (Pl. XIII. fig. 1). They are represented by Miller,[4] Austin, and also by Quenstedt;[5] and were continued upwards into those "which cover the dome-like integument over the abdominal pouch,[6] just exactly as is the case with their fellows in recent forms.

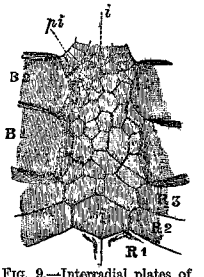


FIG. 9.—Interradial plates of *Apiocrinus roissyanus* (after de Loriol). B1, B2, first and second brachials; R1, R2, R3, first, second, and third radials; *pi*, basal joints of lowest pinnule; *I*, calyx-interradial, resting on the upper angles of two first radials (R1); *i*, smaller interradials, but probably only perisomic plates.

The Silurian genera *Glyptocrinus*, *Reteocrinus*, and *Xenocrinus* appear to me to have been in the same condition; though I will not go so far as to say that the mouth was open to the exterior. For the peristome may well have been closed by the more or less well defined apical dome plates, which covered the central part of the disk, just as in the Ichthyocrinidæ. The vault of *Glyptocrinus* is best known in *Glyptocrinus decadactylus*. According to Miller[7] "The regular interradial areas have one plate resting upon the primary radials, two in the second range, three in the third, two or three in the fourth,

[1] Revision, part i. p. 54.
[2] *Hist. Nat. des Crinoïdes*, p. 21, pl. iii. figs. 1, 3.
[3] Paléont Franç., *loc. cit.*, pp. 272, 273.
[4] *Op. cit.*, pp. 57, 59.
[5] Encriniden, Tab. 101, fig. 39*a*.
[6] Austin, *op. cit.*, p. 104, pl. xiii. figs. 1*a*, 1*c*, 1*k*.
[7] *Glyptocrinus* redefined and restricted, *Gaurocrinus*, *Pyenocrinus*, and *Compsocrinus* established, and two new species described, *Journ. Cincinn. Soc. Nat. Hist.*, vol. vi. pp. 220, 221.

and above these fifteen or twenty small plates in each depressed intertertiary area. Intersecondary radial areas have one rather large plate in each axil, and a dozen or more smaller ones filling the depressions between the tertiaries. Intertertiary areas have in like manner one plate in each axil, and several smaller ones above. . . . The vault is somewhat convex in the central part, and undulates towards each intertertiary area. It is composed of numerous polygonal plates. Those in the central part are the larger ones, and each of these bears a central tubercle, which is sometimes prolonged so as to be designated a spine toward the margin, or rather following the undulations toward the intertertiary areas, the plates are smaller and possessed of slight convexity. They unite in the depressions in the intertertiary areas with the plates of the calyx, or rather the interprimary radials graduate through the intersecondaries and intertertiaries to the plates of the vault without any line of separation. The plates become smaller as they approach the inner face of the arms, over the swelling undulations of the vault, and continuing to decrease in size, form a somewhat granular continuous integument, that covers the ambulacral furrows."

Except as regards the larger central plates (orocentral and orals), this description would apply equally well to the disk of many Pentacrinidæ and Comatulidæ. The vault of *Glyptocrinus* would appear to have been more or less flexible as in the Ichthyocrinidæ; and the so-called "continuation of the vault up the inner side of the arms" seems to me to be nothing but the extension on to the arms of the ambulacral skeleton, together perhaps with some of the anambulacral plates at its sides, just as in *Pentacrinus asterius*, *Pentacrinus alternicirrus*, *Pentacrinus naresianus*, and *Metacrinus murrayi* (Pl. XVII. fig. 7; Pl. XXVI. figs. 1, 2; Pl. XXVII. fig. 13; Pl. XXX. fig. 2; Pl. XLI. fig. 13).

The vault of *Retocrinus nealli* is thus described by Meek[1] "Interradial areas occupied by numerous (70 to more than 100) small pieces of very irregular size and form, and without any definite arrangement. . . . Axillary areas each occupied by about fifty to sixty very small, irregularly arranged, unequal pieces. Vault composed of numerous minute pieces, generally of hexagonal form; highest on the anterior side, with a ridge radiating to each arm-base, and a corresponding sulcus between; opening minute, penetrating a small tubercle situated behind the middle, and directed backward."

Wachsmuth says that the plates in the median part, which probably include the apical plates, are somewhat larger than the rest; while he further states that "the peculiar depressed state of the interradial and interaxillary areæ, the irregularity with which their plates are arranged, suggests the possibility that they were adapted to expansion by the animal."[2] Here again, then, he admits the possibility of the "vault" having been pliant and flexible. Thanks to his kindness, I have had the opportunity of examining specimens of all three genera, *Glyptocrinus*, *Reteocrinus*, and *Xenocrinus*, while Meek gives an excellent figure of the summit in *Reteocrinus nealli*.[3] I am sorry,

[1] Palæontology of Ohio, vol. i. p. 35. [2] Revision, part ii. p. 192. [3] Palæontology of Ohio, vol. i., pl. ii. fig. 3c.

however, that I cannot agree with Wachsmuth respecting its nature. For, like that of *Ichthyocrinus*, it appears to me to represent the plated ventral perisome of the Neocrinoids; while the ridges which radiate to the arm-bases seem to me to consist of the covering plates of the ambulacra. I do not deny that they may have been closed down, either temporarily as in the recent *Pentacrinus wyville-thomsoni* (Pl. XVII. fig. 6), or permanently as in *Platycrinus*. But I cannot imagine that they represent parts of a solid vault like that of *Actinocrinus*.

I would say the same of *Xenocrinus*, of which Miller[1] speaks as follows: "Interradial and intersecondary radial spaces. . . . These long, narrow, depressed areas are covered with small plates, having a tubercle or short spine in the central part of each. There are more than seventy-five plates in each interradial area, and twenty-five or more in each intersecondary radial area before reaching the top of the cup, but the small plates continue over the margin of the vault, and undoubtedly cover it, and also more or less of the long proboscis, which is extended from the anterior or azygous side."

Wachsmuth denies that any Palæocrinoid is known in which the existence of a solid vault has been disproved or cannot be traced by analogy; and also that there can be any homology between this solid vault and the ventral perisome (whether soft or plated) of a Neocrinoid. He has since admitted, however, that the radial pieces in the vault of *Cyathocrinus* and *Platycrinus* correspond to the ambulacral skeleton on the external surface of the body of recent Crinoids; and I venture to think that in the case of *Glyptocrinus*, *Reteocrinus*, and *Xenocrinus*, and also of the Ichthyocrinidæ, the resemblance to the Pentacrinidæ, Apiocrinidæ, and Comatulæ is such as to leave no reasonable doubt that the so-called vault of these Palæocrinoids is homologous with the ventral surface of the body in the Neocrinoids. Except as regards *Coccocrinus*, however, I am not prepared to deny that the mouth was subtegminal, *i.e.*, concealed beneath the apical dome plates, which I regard as representing a permanently closed oral pyramid. When the presence of these plates has been demonstrated in *Coccocrinus*, I will admit that the "Scheitelstücke" which Allman, Wachsmuth, Zittel, and myself have all considered as orals, belong to the interradial system, and do not surround an open mouth as the orals of *Holopus*, *Hyocrinus*, and *Thaumatocrinus* do.

[1] *Journ. Cincinn. Soc. Nat. Hist.*, vol. iv. p. 72.

XI.—CLASSIFICATION.

The following is the classification of the Stalked Echinoderms which is adopted in these Reports :—

Phylum, ECHINODERMATA.

Branch, PELMATOZOA.

Class 1. CRINOIDEA.
Class 2. CYSTIDEA.
Class 3. BLASTOIDEA.

Synonymy and other Classifications.

PELMATOZOA, Leuckart, 1848.	*Crinoidea*, Burmeister, 1856.	Brachiata.	1. Crinoidea, *sensu. str.*
		Anthodiata.	2. Cystidea.
			3. Blastoidea.
	Crinoidea, Roemer, 1856.	An order of the class Echinodermata.	1. Actinoidea = Crinoidea, *sensu. str.*
		Three suborders.	2. Cystidea.
			3. Blastoidea.
	Tentaculata, Ray-Lankester, 1877.	A branch of the Phylum Echinodermata.	I. Crinoidea.
		Three classes.	II. Blastoidea.
			III. Cystidea.
	Crinoidea, Zittel, 1880; and de Loriol, 1882.	A class of the Stamm Echinodermata.	1. Eucrinoidea = Crinoidea, *sensu. str.*
		Three orders.	2. Cystoidea.
			3. Blastoidea.

PELMATOZOA.

Definition.—Echinoderms which are fixed either permanently or temporarily by the middle of the aboral surface. A jointed stem containing a neuro-vascular axis is usually present, but may be lost when maturity is reached; or, in the case of a few sessile forms,

remain altogether undeveloped. The apical system consists of a dorsocentral plate, basals, and radials, with the frequent addition of under-basals and interradials. These plates form a cup, which either simply supports, or more or less completely encloses the visceral mass, and often bears jointed appendages, the arms and pinnules.

An oral system, consisting of a central plate (orocentral) and five orals is developed above the peristome of the larva to a very variable extent, and may be either altogether resorbed, or reach a high degree of importance by the appearance of additional plates so as to form a vault or "*tegmen calycis*." The anus is situated on the oral surface, which may be bare, or more or less covered by calcareous plates. The water-vascular ring does not communicate directly with the exterior, and the lateral branches of the radial vessels (when present) are respiratory, but not locomotor in function.

Class 1. CRINOIDEA, Miller, 1821.

Crinoidea, Auctorum.
Stilasteritæ, Goldfuss, 1826–1835.
Asterencrinidea, de Blainville, 1834.
Pinnigrada, Forbes, 1841.
Pinnastella, Austin, 1842.
Brachiata, Burmeister, 1856.
Actinoidea, Roemer, 1856 (Date of Preface).
Encrinidæ, Quenstedt, 1876 (Date of Preface).
Eucrinoidea, Zittel, 1880 (Date of Preface).

Definition.—Pelmatozoa, in which the radial plates of the calyx bear more or less branching arms. These consist of segments which are articulated by means of muscles and ligaments, and in most cases bear similar jointed appendages, the pinnules. The nervous system consists (1) of a central organ situated in the calyx, and fibres extending from it through the skeleton of the stem, arms, and pinnules; (2) of a circum-oral ring and radial extensions which are in close relation with the ciliated epithelium of the ambulacral grooves. These are more or less extensively distributed on the ventral surface of the disk, arms, and pinnules; and are bordered by groups of tentacles which alternate on opposite sides. When they are absent, the radial water-vessels give off no tentacular branches. The water-vascular ring opens by five or more water-tubes into the body-cavity, which itself communicates with the exterior by a corresponding number of water-pores. The mouth is central, except in one genus, and the anus subcentral or excentric. The genital glands are lodged in the lower parts of the arms, but are usually fertile only in the pinnules.

Remarks.—Various writers have attempted at different times to separate the Crinoids and their allies from the remaining classes of the Echinoderms by somewhat more definite characters than those which distinguish these various classes *inter se*. Very little was

known, however, respecting the anatomical relations of the soft parts of a Crinoid; while the morphology of the Echinoderms generally was far from being properly understood; and in most cases the group was regarded as consisting of four or five divisions of equal value, which were considered as classes or orders according to the position assigned to the Echinoderms generally in the animal kingdom. The Ophiurids and Asterids have sometimes been united into one group, the Stellerids, which, though convenient for purposes of reference, appears to me to be somewhat too comprehensive. Considering the totally dissimilar modes of development, and the great difference in anatomical structure between a Brittle-star and a Starfish, I find it difficult to do otherwise than regard the Ophiuroidea and Asteroidea as independent classes of Echinoderms, of equal systematic value with Echinoidea and Holothuroidea.

In like manner, I should rank the Blastoidea and Cystidea as classes of the Echinoderms rather than as sub-classes or orders of the Crinoidea. The essential difference between them and the true Crinoids (*Eucrinoidea* of Zittel and de Loriol) is the presence in the latter of branching articulated arms developed above the radial plates of the calyx; while the symmetrical composition of the calyx in the Blastoids, the complexity of their ambulacra, and the regular arrangement of their hydrospires, sharply distinguish them from most of the Cystids, the morphological characters of which are, as it were, more plastic and less crystalline.

These three groups, however, the true Crinoids, the Blastoids, and the Cystids, are distinguished from the remainder of the Echinoderms by certain very definite peculiarities, *i.e.*, the more or less permanent attachment of the aboral surface of the body, and the absence of any locomotor organs in connection with the ambulacral system. For the lateral branches of the water-vessels, when present, are simple respiratory tentacles of an altogether different nature from the tube-feet of an Echinid or Stellerid.

Important as these differences are, few zoologists seem to have recognised them as of any greater systematic value than those between an Urchin and a Starfish, Crinoidea, Asteroidea, and Echinoidea having been generally regarded as equivalent divisions of Echinoderms. As long ago as 1848, however, Leuckart separated the stalked Echinoderms from the remainder of the group under the name "Pelmatozoa." This suggestion seems to have been adopted by Bronn in 1860,[1] while Leuckart classed the Echinoderms in accordance with it in his annual "Berichte;" but little notice was taken of it in this country except by Sir Wyville Thomson, as will be seen further on. In 1869 Prof. Huxley[2] recognised the same principle when he wrote "The Crinoids are so different from the other living Echinodermata that they will probably have to form a distinct primary division or sub-class of the class; and this may possibly be the

[1] Die Klassen und Ordnungen des Thier-Reichs, Bd. ii., Aktinozoen, 1860, pp. 3, 421.
[2] An Introduction to the Classification of Animals, London, 1869, p. 130.

case with some of the following extinct forms," viz., Cystidea, Edriasterida, and Blastoidea.

The difference in the functions of the water-vascular system between the stalked and the unstalked Echinoderms respectively was applied by Prof. Ray Lankester for systematic purposes in his division of the Echinoderms into *Ambulacralia* and *Tentaculata*, the latter including Crinoids, Cystids, and Blastoids.[1]

The name "Tentaculata" is unfortunately open to the objection that even in recent Crinoids some of the radial water-vessels may be totally unprovided with tentacles at their sides; while if, as I believe, the water-vessels of the Blastoids occupied the subambulacral canals within the lancet-pieces,[2] they must certainly have been non-tentaculate. To one division (class) of the group, therefore, the name "Tentaculata" would not be at all applicable. Neither do I like the extension of the term "Crinoidea" to the Blastoids and Cystids, and the consequent limitation of the brachiate forms by the name Eucrinoidea, which we owe to Zittel so far as I have been able to trace it; though it has recently been adopted by de Loriol.

In Miller's original definition of the Crinoidea[3] he described them as having "a cup-like body containing the viscera, from whose upper rim proceed five articulated arms, divided into tentaculated fingers more or less numerous." The presence of these arms is essential to the idea of a "lily-shaped animal." The very characteristic appearance of the Crinoid type is lost if the arms be not attached to the calyx; while morphologically they are of the utmost importance.

On the other hand, jointed appendages of this kind, attached to the rim of the cup, and containing radial extensions of the nervous axis of the stem, as well as of all the ambulacral structures which surround the peristome, together with the genital glands, are entirely absent both in the Blastoids and in the Cystids. In the former group, it is true, there were jointed appendages at the sides of the ambulacra; but although the latter are very often spoken of as "recumbent arms," they are not composed of articulated pieces, and only a very general homology can be traced between them and the branching arms of a Crinoid. In the Cystids, however, segmented arms somewhat like those of Crinoids seem to have been occasionally present, and even grooved by the ambulacra. But they were mostly attached somewhat irregularly in the neighbourhood of the mouth, and not to the radial portions of the cup as in the Crinoids; and I much doubt whether their component segments were regularly articulated together.

Neither the Blastoids nor the Cystids, therefore, can properly be classed as Crinoidea, in the sense of Miller's definition of the group; though this has been very frequently done during the last forty years, more especially by continental naturalists. Von

[1] Notes on Embryology and Classification, *Quart. Journ. Micr. Sci.*, 1877, vol. xvii., N. S., p. 444.

[2] On Certain Points in the Morphology of the Blastoidea, *Ann. and Mag. Nat. Hist.*, 1881, ser. 5, vol. viii., p. 420; *Ibid.*, 1882, vol. ix. p. 218.

[3] *Op. cit.*, p. 7.

Buch, however, clearly distinguished the essential differences between Crinoids and Cystids.[1] The same was the case with Edward Forbes, who having given the Crinoids ordinal rank in 1841[2] under the remarkable name "Pinnigrada," assigned the same position to the Cystids in 1848.[3] Von Buch seems to have considered the Blastoids as a third group of equal value with these two. Roemer, on the other hand, degraded the Cystidea and Blastoidea to the level of families or sections of the order Crinoidea, separating off the brachiate forms of the latter as true Crinoidea.[4] A few years later he proposed to call these by the name "Actinoidea," and to rank them together with Blastoids and Cystids as suborders of the Crinoidea.[5] This term was thus employed, not in the strict sense of Miller's original definition, but as co-extensive with the name "Pelmatozoa," which had been proposed by Leuckart four or five years previously; though Roemer appears to have been unacquainted with it. This was unfortunate, as the use of Leuckart's excellent name in the Lethaea Geognostica would have avoided much subsequent confusion.

In the second volume of Bronn's "Thier-Reich" the Echinoderms aret hrown together with the Cœlenterates into the comprehensive "Kreis" of Strahlenthiere or Aktinozoa. Four classes of Cœlenterates are first considered, and then the Blastoidea and Crinoidea, for which the cumbersome names "Blastactinota" and "Crinactinota" are proposed. Fortunately, however, they have not come into general use. The Cystids are thrown back among the Crinoids, for Bronn did not consider them as differing from the brachiate Crinoids to the same degree as the Blastoids. This was altogether in opposition to the views of Von Buch and Edward Forbes, and also to those of Roemer,[7] to whom the peculiarities of the Blastoids and Cystids appeared so marked, "dass sie als gleichwerthige, wenn auch nicht gleich umfangreiche Sectionen oder Unterordnungen den ächten Crinoiden entgegen zu setzen sind." Viewed by the light of later knowledge, Bronn's classification was of a distinctly retrogressive nature.

Besides the Cystids he recognised two other divisions of the Crinoidea, viz., the Brachiata or the Crinoidea proper, and the Costata, Müller, the latter including the problematical *Saccosoma*.

The terminology employed by Bronn for the different groups of the stalked Echinoderms is extremely difficult to understand, and appears to contain many errors. Thus on pp. 193 and 421 (*op. cit.*), the name "Actinoidea" for the true Crinoids is attributed to Müller, though it is really Roemer's, as explained above; while on pp. 207 and 210 the true Crinoids are referred to as "Anthodiata," in contradistinction to the other division

[1] Ueber Cystideen, *Abhandl. d. k. Akad. d. Wiss. Berlin*, 1845, pp. 12, 13, 17, 27.

[2] A History of British Starfishes and other Animals of the class Echinodermata, London, 1841, p. xiv.

[3] On the Cystideæ of the Silurian Rocks of the British Islands, *Mem. of the Geological Survey of Great Britain, and of the Museum of Practical Geology*, 1848, vol. ii. part 2, pp. 526, 527.

[4] Monographie der fossilen Crinoiden-familie der Blastoideen, und der Gattung Pentatrematites im Besondern, *Archiv f. Naturgesch.*, Jahrg. xvii., Band i. pp. 387, 388.

[5] Lethaea Geognostica, Bd. i., Theil 2, p. 224.

[6] *Op. cit.*, pp. 180, 193.

[7] Lethaea Geognostica, Bd. i. Theil 2, p. 224.

of the "Crinactinota," viz., the Cystids. On the other hand, according to the scheme on p. 421, "Anthodiata" was the name proposed by Burmeister for the Blastoids, while the term "Brachiata" was also his, and included the true Crinoids and the Cystids. On pp. 3, 227, and 230, however, the term "Brachiata" is used by Bronn to denote the true Crinoids only, and it is attributed to Müller. Zittel has followed Bronn in this respect, and, as I believe, erroneously. For I have searched Müller's writings on Crinoids repeatedly without finding this expression, though frequent reference is made to the "Crinoidea Tessellata mit Armen."

After various unsuccessful attempts to discover where Burmeister's nomenclature was published, I applied to Prof. F. J. Bell, who was kind enough to make a search in the library of the Zoological Department at the Museum of Natural History, with the following result. In his Zoonomische Briefe, published at Leipzig in 1856 (vol. i. p. 243), Burmeister gives the following "Systematische Uebersicht der Crinoideen."

I. *Crinoidea anthodiata.*

1. Cystideen. 2. Blastoideen.

II. *Crinoidea brachiata.*

3. Tessellaten. 4. Articulaten. 5. Gesippten (*Crinoidea costata*). 6. Holopus.

This classification of Burmeister's deserved more attention than it has hitherto received; for it was the first which clearly brought out the difference between the true Crinoids with segmented arms attached to the radials and the "Anthodiata" or Blastoids and Cystids, in which there are either no arms at all or structures of an entirely different nature from those of the true Crinoids. In this, as in other respects, the Blastoids and Cystids at once differ from the Crinoids and resemble each other. In fact they are so closely linked together that it is extremely difficult to refer forms like *Hybocystites* and *Cystoblastus* to one group rather than to the other.[1]

The term Crinoidea should, I think, be limited to the strictly brachiate forms for which it was proposed by Miller; and it is much less applicable to the stalked Echinoderms generally than Leuckart's name "Pelmatozoa." But except as regards this question of nomenclature Burmeister's classification agrees far better with our present knowledge than many of those published before or since his time, *e.g.*, that of d'Orbigny, Pictet, or of Dujardin and Hupé.

Low as the Cystids had fallen in Bronn's classification from the ordinal position to

[1] Quenstedt has solved the difficulty respecting the systematic position of *Cystoblastus* by describing it twice over. On p. 684 of his "Encriniden" it appears among the Cystids, and is figured on Tab. 113, fig. 89; but on p. 724 it is described as a Blastoid, and it is figured on Tab. 114, fig. 98, under the name of *Cycloblastus*.

which they had been raised by Forbes, they had been, and were subsequently, still further degraded. For d'Orbigny[1] took an entirely different view of the characters of the various types of the Pelmatozoa from those held by some of his predecessors; and he not only threw the Cystids and Blastoids back among the Crinoids, but he considered these two groups merely as families. He divided the order Crinoidea into twelve families, among which are the Comatulidæ, Pentremitidæ, Cystidæ, and lastly the Pentacrinidæ; and Pictet[2] subsequently reduced this number to nine, but without making any change in the four above mentioned.

Dujardin and Hupé[3] also adopted this singular arrangement, according to which the differences between a *Pentacrinus* and a *Pentremites*, *Echinosphærites* or *Actinocrinus*, are of no greater systematic value than those between *Pentacrinus* and *Comatula*. In this country, however, thanks mainly to the teaching of Prof. Huxley,[4] Crinoids, Cystids, and Blastoids have always been regarded as independent but equivalent divisions, formerly orders, but now classes of the Echinodermata. To these Huxley[5] has since added another, as to the necessity for which there has been a considerable difference of opinion, viz., the Edriasterida.

This group, which includes the curious sessile forms *Agelacrinus*, *Edrioaster*, and their allies, has been generally placed among the Cystids; but it has been re-established quite lately under the name of Agelacrinoidea by S. A. Miller, in ignorance of Prof. Huxley's classification of fifteen years ago.

I am inclined to think myself that if these forms be anything more than the isolated disks of Palæocrinoids, as was thought possible by Sir Wyville Thomson (*ante*, p. 85), their proper place is among the Cystids.

Two other new orders (*i.e.*, classes) of the class (*i.e.*, subkingdom) Echinodermata have recently been proposed by S. A. Miller.[6] These are the Lichenocrinoidea and the Myelodactyloidea. But I cannot regard them as of equal value with the Crinoids, Cystids, and Blastoids. Our knowledge of the structure of *Lichenocrinus* is of the most limited character; and it is therefore totally insufficient for the basis of a class definition. The same may be said of *Cyclocystoides*, which together with the so-called *Myelodactylus* is placed by Miller in a new order that he proposes to call Myelodactyloidea. Whatever be the nature of *Cyclocystoides*, there can, I think, be little doubt that Salter, Charlesworth, and more recently Nicholson and Etheridge[7] were right in regarding the

[1] Cours élémentaire de Paléontologie et de Géologie stratigraphique, Paris, 1852, t. ii. fasc. i. p. 134.

[2] Traite de Paléontologie, t. iv. p. 282.

[3] Histoire Naturelle des Zoophytes, Échinodermes, Paris, 1862, pp. 55–58.

[4] Lectures on General Natural History, *Medical Times and Gazette*, November 1856, p. 463.

[5] An Introduction to the Classification of Animals, London, 1869, p. 130.

[6] Description of three New Orders and four New Families, in the class Echinodermata, and eight New Species from the Silurian and Devonian Formations, *Journ. Cincinn. Soc. Nat. Hist.*, vol. v. pp. 221–223.

[7] A Monograph of the Silurian Fossils of the Girvan District in Ayrshire, Edinburgh, 1880, pp. 330–334.

supposed arms and pinnules which were described by Hall as *Myelodactylus*[1] as a coiled up stem of peculiar structure. It may perhaps belong to some Crinoid of which the head is not yet known; but until Salter's statements[2] have been satisfactorily refuted by Hall or Miller, I cannot admit the Myelodactyloidea as a class of Echinoderms equivalent to the Crinoidea, Ophiuroidea, or Blastoidea.

The Echinoderms which have no tube-feet in their ambulacra, and are more or less permanently attached by their aboral surface, seem to me therefore to fall very naturally into three classes, Crinoidea, Cystidea, and Blastoidea. They have several characters in common which sharply distinguish them from the other Echinoderms, and serve to define the branch or division PELMATOZOA, Leuckart, which is of course synonymous with Crinoidea in the widest sense.

I am indebted to my friend Prof. F. Jeffrey Bell for the reference to Leuckart's original definition of the group. I heard the name first from Sir Wyville Thomson, who was greatly struck with its appropriateness, and introduced it into the syllabus of his class lectures. He could, however, give me no reference to it; but Prof. Bell was fortunately able to find it in Leuckart's Bericht über die wissenschaftlichen Leistungen in der Naturgeschichte der niederen Thiere for 1864–65, where the Echinoderms are divided into *Pelmatozoa*, *Echinozoa*, and *Scytodermata* (Holothurians). Working back from this year Prof. Bell eventually succeeded in tracing back this classification of Leuckart's to a morphological essay published in 1848, where, however, the familiar name ACTINOZOA is used to denote the Urchins and Starfishes together. After alluding to the essential characters of the Pelmatozoa, *i.e.*, the presence of a stem either temporarily or permanently, Leuckart referred to the two orders of this class, the Cystids and the true Crinoids.[3] The latter is distinguished by the fact that "An dem obern peripherischen Rande des Kelches noch besondere zahlreich gegliederte Arme sich vorfinden, deren Skeletstücke immer dem Perisom angehören und stets von dem dorsalen Pole ihren Ursprung nehmen." In this description of the Crinoids, as well as in the prominence given to the presence or absence of a stalk in the morphology of the Echinoderms, Leuckart seems to me to have been peculiarly fortunate. The only point to which one might be disposed to take exception, and it is in reality more a verbal one than anything else, is his description of the arm-skeleton as belonging to the perisome; for the term "perisomatic" skeleton is now somewhat limited in its meaning (*ante*, p. 73).

The Pelmatozoa therefore differ altogether from other Echinoderms in the presence of a stem, and in the consequent departure from the ordinary habits of an Urchin, Starfish, or Holothurian. Whether sessile, or provided with a stem, the Crinoid lies on its aboral surface, instead of creeping about mouth downwards in search of food. The lateral

[1] Palæontology of New York, 1852, vol. ii. p. 191, pl. xlii. figs. 5, 6.

[2] Catalog. Camb. Silur. Foss. Woodw. Mus., Cambridge, p. 118.

[3] Ueber die Morphologie und die Verwandtschaftsverhaltnisse der wirbellosen Thiere, Braunschweig, 1848, p. 42.

branches of the water-vessels are therefore either absent altogether as in the Blastoids and in some of the arms in many *Actinometræ*; or they supply delicate papillate tubules, the tentacles, the chief functions of which are probably those of respiration and sensation. Ludwig's researches have demonstrated that the primary water-pore of the *Antedon*-larva is homologous with the commencing madreporite of an Echinozoon. But in no Starfish or Urchin is the communication between the water-vascular system and the exterior effected through the intervention of the body-cavity as it is in the adult forms of recent Crinoids, whatever be the condition of the larva. There is good reason to believe that the hydrospires of the Blastoids and Cystids were neither connected with the water-vascular ring nor with the body-cavity, so that the absence of a continuous madreporic canal may be regarded as eminently characteristic of the Pelmatozoa, though it occurs in some Holothurians and possibly also in certain Ophiurids.

The limitation of the functions of the water-vascular system in the Pelmatozoa, although a natural consequence of the presence of the stem, is in no way connected with this organ morphologically. With the blood-vascular and nervous systems, however, the case is different.

There can be little doubt that the remarkable neuro-vascular axis which occupies the central canal of the stem of a Neocrinoid, occupied a similar position in the Palæocrinoids. Even in the case of sessile forms like *Edriocrinus* there must have been a chambered organ, from the fibrillar envelope of which were derived the axial cords of the rays and arms, just as in the recent *Holopus*. The Blastoids all have basal and radial plates, and, with the exception of the Astrocrinidæ, a perforated stem, so that one can hardly be going too far in assuming that its central canal lodged a neuro-vascular axis, as in recent Crinoids. The same is probably true of the pedunculate Cystids; though I much doubt whether the Agelacrinidæ had a chambered organ. This peculiar structure, which is so important a part both of the blood-vascular and of the nervous systems, is essentially anti-ambulacral, being developed in the right larval antimer. With its connections it is as important a part of the organisation of a Pelmatozoon as the cerebro-spinal axis is in a vertebrate animal; and there is in many respects a striking analogy between the two.

Although in such intimate relation with the basal and radial plates, the chambered organ cannot be correlated with their presence; for true homologues of these plates occur in the Echinozoa, in none of which have any traces of an aboral neuro-vascular centre yet been discovered.

There are two characters, however, by which some or all of the Pelmatozoa are especially distinguished, viz., (1) the presence of a stem, and (2) the development of arms upon the primary radials, with muscular articulations between their component joints. The majority of the Pelmatozoa have both stem and arms, but the Astrocrinidæ seem to have had neither, though possibly stalked when young; while the remaining Blastoids

and the Cystids had no such arms, and the Holopodidæ and *Edriocrinus* were stemless. None of the typical Pelmatozoa, however, are devoid of both stem and arms, with one or both of which the chambered organ seems to be correlated. A so-called pedunculate Starfish has already been described by Prof. Perrier,[1] and it was with much disappointment that I learnt from Mr. Sladen[2] that *Caulaster* is far from being the interesting type which it was at first supposed to be. I am not without hopes, however, that future morphological work upon Urchins and Starfishes may throw more light upon this question; and there is very much to be done by those who will go into the study of the Palæozoic Starfishes equipped with a knowledge of the morphology of recent Echinoderms, and will not be content with merely compiling empirical descriptions of new species.

Müller's original classification of the true or brachiate Crinoids divided them into three groups, Articulata, Tessellata, and Costata, the last including the problematical genus *Saccosoma*, which may perhaps eventually turn out to be an Ophiurid. Reference has already been made (*ante*, pp. 145–147) to the unsuitability of the Müllerian names Articulata and Tessellata for the two other principal divisions of the brachiate Crinoids. The latter is practically co-extensive with the Palæocrinoidea of Messrs. Wachsmuth and Springer.[3] These authors have gone further than Zittel and de Loriol, and have proposed to divide up the Crinoidea (understood in the widest sense) into the following orders:—(1) Blastoidea; (2) Cystoidea; (3) Palæocrinoidea; (4) Stomatocrinoidea; (5 ?) Costata. This classification, however, has been by no means generally accepted. Different as are many of the Palæocrinoids, *e.g.*, *Eucalyptocrinus*, from a Pentacrinite, others, such as the Ichthyocrinidæ, have many of the characters of a recent Crinoid; and an arrangement which elevates the difference between *Pentacrinus* and *Ichthyocrinus* to the same importance as those between *Pentacrinus*, *Pentremites*, and *Echinosphærites* respectively, appears to me to be founded on a misconception of the value of morphological characters.

On the other hand, although the definition of the Palæocrinoidea which has been given by Wachsmuth and Springer is capable of improvement in one or two respects, it is far more correct and is based upon sounder morphological principles than any definitions of the Tessellata which have been drawn up by Müller and his followers. But I cannot regard the two groups Palæocrinoidea and Stomatocrinoidea (Articulata or Neocrinoidea) as equivalent to the Blastoids and Cystids; so that while keeping the Palæocrinoids at the level of an order, I should rank the Blastoidea and Cystidea as classes, in accordance with the practice generally adopted in this country.

Prof. Chapman[4] has proposed a classification of the brachiate Crinoids which "is

[1] Sur une Astérie des grandes profondeurs de l'Atlantique, pourvue d'un pédoncule dorsal, *Comptes rendus*, t. xcv. pp. 1379–1381.

[2] The Asteroidea of H.M.S. Challenger Expedition, part ii., *Journ. Linn. Soc. Lond.* (Zool.), vol. xvii. p. 217.

[3] Revision, part ii. p. 3.

[4] A Classification of Crinoids. *Trans. Roy. Soc. Canada*, vol. i., 1883. Section iv., 1882, pp. 113–116.

based essentially on the presence or absence of a canaliculated structure in the calyx and arm plates." The last of his three leading divisions, the Canaliculata, corresponds to the Articulata, Müller; but Chapman's name does not appear to me to be so greatly superior to Müller's that it could be adopted without hesitation. *Platycrinus*, *Marsupites*, and *Uintacrinus* have perforated first radials. They are, however, placed by Chapman among the Emedullata, in which "the calyx plates are without internal canals."

The absence of canals in the calyx plates is a character of very general occurrence among the Palæocrinoids, and one which does not present itself in any adult Neocrinoid. But there are several Palæocrinoids in which it does not occur at all, and it cannot therefore be used as the principal "differentia" for separating the older (Tessellate) from the younger (Articulate) Crinoids.

Reasons have already been given for preferring the name "Neocrinoidea" for the latter group to either Stomatocrinoidea or Articulata. The second of these names is certainly founded upon a misconception, and I believe the same to be the case with the first one; while neither of them was ever properly defined by its author. The name Neocrinoidea is coming gradually into use; and as the essential differences between this order and that of the Palæocrinoidea have already been discussed in Chapter X., it is not necessary for me to go into them again, though they may be conveniently put in the form of a definition.

Order NEOCRINOIDEA.

Crinoids with a regularly pentamerous calyx, which is generally without primary interradial plates, and except in one genus has no anal or azygous side. The calyx-radials are perforated, and are generally united to the succeeding plates by a muscular articulation. The rays may remain simple, or divide from one to eight times, the first axillary being usually the second joint after the primary radials of the calyx. Orocentral plate probably never developed; orals, when present, may be limited to larval existence, or remain through life partially covering the peristome, but capable of being separated so as to open the mouth to the exterior. The oral surface of the visceral mass, with the ambulacra traversing it, may be more or less paved by plates, but is not in any way covered up and shut off from the exterior by a vault.

XII.—DESCRIPTION OF THE SPECIMENS.

Class CRINOIDEA.

Order NEOCRINOIDEA.

Family HOLOPIDÆ, Roemer, 1856; *emend.* Zittel, 1879, and P. H. Carpenter, 1884.

Genus, *Holopus*, d'Orbigny, 1837; *emend.* P. H. Carpenter, 1884.

A. GENERAL ACCOUNT OF THE TYPE.

Definition.—Basals and radials completely anchylosed into an asymmetrical tube-like calyx, which is fixed by an irregularly expanded base. On the upper edge of the cup are five unequal articular surfaces for the attachment of the second radials. Arms ten, massive, and closely inrolled. Disk relatively small, with a central mouth protected by five oral plates, between which and the edge of the cup is a very narrow irregular pavement of smaller plates. Anus probably present, but not yet observed.

Remarks.—The description of this genus, which was established by d'Orbigny in 1837, attracted much attention on account both of the novelty and of the rarity of this singular type. The specimen described by d'Orbigny, which was for a long time unique, was brought from Martinique by M. Sander Rang. It is tetta- instead of penta-radiate as most Crinoids are, and this seems to have caused some misconception respecting its true nature, for it receives no mention whatever in Pictet's Paléontologie; while Dujardin and Hupé[1] expressed their opinion in 1862 that *Holopus* is not a Crinoid at all, but an altogether different type, probably a Cirripede.[2]

A few years later, however, a normal pentaradiate example was brought up on a fisherman's line from deep water off Barbados. It was fortunately acquired by the governor, Sir Rawson Rawson, and was placed by him in the hands of Prof. Louis Agassiz during the stay of the "Hassler" at Barbados in 1872. Prof. Agassiz intended to have published a full description of the specimen, but was prevented from doing so by failing health, and after his death the figures which he had prepared were published by Mr. Alexander Agassiz, together with a short descriptive note by Count Pourtalès.[3]

[1] Mémoire sur une seconde espèce vivante de la famille des Crinoides ou Encrines, servant de type au nouveau genre Holope (Holopus), *Guérin, Mag. de Zool.*, 7me année, Classe x., 8 pp., pl. 3, Paris, 1837.

[2] *Op. cit.*, p. 218.

[3] Description of a Specimen of Holopus rangii from Barbados, *Mem. Mus. Comp. Zoöl.*, vol. iv. No. 8, p. 51.

This specimen was subsequently entrusted by Sir Rawson Rawson to Sir Wyville Thomson, together with two others which he had obtained in 1876, after the publication of Pourtalès' notice of the first one. Sir Wyville described the three as follows:[1] "One is very complete in all important points, wanting only the two 'bivial' arms, but retaining the mouth-valves. The second is a little larger; it wants the mouth-valves, and again the bivial arms; and with Sir Rawson Rawson's sanction I boiled this specimen down to figure and describe the separate parts. The third specimen is quite perfect, the arms closely curled in in their normal position when contracted; but it is very young, only about 8 mm. in height. Besides the four examples mentioned, I am aware of only another which I have not yet seen; it was shown at the Philadelphia Exhibition, and was afterwards bought by the Museum of Comparative Zoology at Cambridge, Mass."

The second of these seems to have been the original specimen described by Pourtalès, from which the oral plates or mouth-valves had dropped away; and as it was gradually falling to pieces from natural decay, Sir Rawson Rawson allowed it to be dissected. The figures on Pl. III., with the exception of fig. 2, and figs. 1–4 on Pl. V., show the results of this process. Fig. 2 on Pl. III. is a slightly idealised view of the interior of the cup, so as to show the oral plates of the large specimen represented in Pl. II.[2] This was supposed by Mr. Murray to belong to Sir Rawson Rawson, and as it corresponds to No. 1 of Sir Wyville's list, I quite imagined this to be the case; but Sir Rawson Rawson does not recognise it as his, and I conclude therefore that it is the mutilated dry specimen which Prof. Agassiz informs me was sent by him to Sir Wyville with permission to cut it up for details. In like manner Sir Rawson Rawson thinks it possible that the original of Pl. IV. may be his young specimen mentioned by Sir Wyville as only about 8 mm. in height, but as Prof. Agassiz tells me that he also sent Sir Wyville a small individual, I fear that two specimens have somehow been mislaid. The one which was shown at the Philadelphia Exhibition, and subsequently bought by the Museum of Comparative Zoölogy, is the original of Pl. I.

It was obtained by Mr. Wilderboer, the collector for Sir Rawson Rawson, after the latter gentleman had left Barbados, and having come into the hands of Prof. Agassiz, it was sent by him to Sir Wyville Thomson, together with the *Holopus* material obtained during the dredging expeditions of the "Blake." This consisted of (1) the very young individual shown in Pl. V. figs. 9, 10; Cruise of 1877–78; Station 22, 100 fathoms; off Bahia Honda, lat. 23° 1′ N., long. 83° 14′ W.; temperature 71° F. (2) The single ray shown in Pl. Vb. fig. 4. This was preserved in spirit, and the greater part of it was subsequently cut into sections. Cruise of 1878–79; Station 157, off Montserrat, 120 fathoms.

[1] On the Structure and Relations of the genus Holopus, *Proc. Roy. Soc. Edin.*, 1877, p. 407.

[2] I did not find this out until too late to alter the notice of the oral plates of *Holopus*, which appears on p. 95. See p. 208.

Holopus rangi, d'Orbigny (Pls. I.–Vb.; Pl. Vc. figs. 1–3).

Dimensions.

	A. (Pl. I.)	B. (Pl. IV.)
Total height,	40·00 mm.	8·50 mm.
Greatest height of cup on trivial side,	15·00 „	4·25 „
Least height on bivial side,	5·25 „	1·75 „
Greatest diameter of upper edge of calyx,	17·00 „	5·00 „
Greatest width of trivial axillary (composite),	13·75 „	3·75 „
Greatest width of arm,	9·75 „	2·00 „
Diameter of smallest specimen (Pl. V.),	3·25 „	
Height of smallest specimen,	1·00 „	

The tubular calyx which is attached by an irregular encrusting calcareous expansion of variable extent, is thick walled, inversely conical, and slightly bent to one side (Pls. I., II., IV.; Pl. III. fig. 1). A more or less distinctly marked constriction separates the spreading base from the actual cup, the greatest height of which, measured on the convex side, is 15 mm. Its cavity narrows very rapidly from above downwards, so that the thickness of its walls, which is everywhere considerable, is greatest at its lower extremity (Pl. V. figs. 1–4); and it is probable that the cup is completely closed below by the spreading base, if not some little way above it.

The analogy of other Crinoids leads one to believe that the cup is composed of radial plates above, and of basals below; but it is difficult to define the limits of either. The radials, however, may be traced downwards some little way, owing to the differences of texture in the limestone network. Sections were made for Sir Wyville Thomson of the least perfect of Sir Rawson Rawson's specimens. The articular faces round the upper edge of the calyx are shown in Pl. V. fig. 1 (compare also Pl. III. figs. 1, 2). They were described as follows by Sir Wyville Thomson[1]—"Each facet is traversed by a transverse articulating ridge, a little in front of which there is the mouth of the tube which lodges the sarcode axis of the joints, and a little behind its centre there is a somewhat longer aperture which appears to lead into the cancellated structure of the outer part of the wall. There are two large shallow muscular impressions on the surface of the facet on the proximal aspect of the transverse ridge." The larger of these two apertures is not the opening of a canal, like the smaller and inner one; but it leads into a deep pit which lodges the dorsal ligament connecting the radials with the joints above them. It reappears upon the proximal faces of these joints, and upon the articular surfaces of all the arm-joints (Pl. III. figs. 3–15). In most Crinoids this pit is merely the deepest part of a large fossa lodging the dorsal ligament (Pl. VIIa. fig. 15, *ld'*. Pl. VIIb. fig. 5; Pl. VIIIa. fig. 7—*ld*; Pl. X. fig. 4; Pl. XX. fig. 7); and there is an approach to this condition in the later arm-joints of *Holopus*, which have a large portion of the articular

[1] *Proc. Roy. Soc. Edin.*, 1876–77, p. 407.

face on the dorsal side of the pit (Pl. III. figs. 14, 15). But on the lower arm-joints and on the radials there is practically nothing of this kind, and the pit lies immediately next to the dorsal edge of the articular face. But the dorsal surface of the joint is strongly convex and produced far below this edge, as is well shown in Pl. III. figs. 5–13. This is also the case with the distal portions of the first radials, as may be learnt from a comparison of figs 1 and 2 on Pl. V. The latter represents a horizontal section of the radials which passes 2 mm. below their edge on the concave (bivial) side, and 7·5 mm. below it on the convex (trivial) side.

Around the opening of the central funnel, which is narrower than at the top of the calyx, is an irregularly shaped pentagonal figure. This is formed by the lines of the transverse articular ridges, which in *Holopus*, as in all other Crinoids, are formed of a much closer and denser limestone reticulation than the remainder of the skeleton. Immediately within these lines are the indications of the small openings of the central canals of the radials; and just outside them are the ends of the pits lodging the dorsal ligaments. The texture of the limestone network forming the inner faces of the radials and the fossæ for the attachment of the muscles and the interarticular ligaments is remarkably different from that of the outer portion of the cup. The two are separated by the lines of the transverse articular ridge, as is shown in fig. 2 on Pl. V. and more distinctly in fig. 7, where the dark line indicates the position of the articular ridge. The substance of the radials inside this line is formed of an irregularly open network, the meshes of which reach 0·08 or 0·09 mm. in diameter, though many of them are much less, sometimes not a quarter that width.

The peripheral portion of the cup, however, is formed of a much more regular network. This consists of concentric and radiating rods which enclose circular or elliptical meshes from 0·015 to 0·035 mm. in diameter, and disposed in regular rows with their long axes tangential. Here and there, as shown in Pl. V. fig. 7, the lines of the meshwork are a little irregular, but its general character is very uniform. The difference between the two types of network is most marked, as much in the regularity as in the size of the meshes, as is well shown in the inner and outer portions of fig. 7, and also in the enlarged portions of limited areas which are represented in figs. 5 and 6. Fig. 8, on the same plate, is an ideal diagram, constructed by Mr. Black, showing the regular disposition of this peripheral reticulation. The difference of the two textures is obvious enough to the naked eye; but it becomes more apparent with the help of a lens which brings out the regularly striated aspect of the outer part of the cup. This is well shown in Pl. V. fig. 2, and less clearly in fig. 4, which represents a section taken about 5 mm. above the basal expansion, and corresponding to the upper face of the vertical section shown in fig. 3.

The central funnel is here much narrowed, and the lines of the articular ridges are seen at a distance of about 1 mm. from its opening. Outside the pentagonal figure

bounded by these lines, the whole of the skeleton is formed by the regular, small-meshed network; while the inner, less dense portion which has a whiter look, narrows gradually downwards as shown in fig. 3, until it entirely disappears from the wall of the diminishing central funnel. There is no trace of it round the greatly reduced opening on the under surface of the segment of the cup which is represented in figs. 3 and 4. In this specimen, as in that represented in Pl. I. and also in d'Orbigny's original, the lowest portion of the calyx-tube immediately above the spreading base, is partially covered with a chitinous-looking layer of variable height, and marked by roughly concentric lines which somewhat obscure the calcareous network beneath. It is merely a thin superficial skin, however, and is evidently of no special importance, or it would be universally present.

The pentagonal figure indicating the position of the articular ridges on the radials is still visible in the section shown in fig. 4, which corresponds to the upper surface of the fragment represented in fig. 3; and the openings of the central canals are also traceable. This would indicate that the greater part of the calyx-tube is composed of elongated radials. One of these canals is seen in nearly longitudinal section in the portion of the lower half of the cup which has been removed to expose the view given in fig. 3. But it is not traceable beyond the limit of the whiter, less dense portion of the skeleton. I strongly suspect, therefore, that this indicates the position of the lower surface of the radials; and the analogy of all other Crinoids would lead to the conclusion that the small portion of the calyx-tube between this and the spreading base consists of closely anchylosed basal plates, the presence of which was taken for granted by Sir Wyville Thomson.[1] There must certainly be a chambered organ, from the fibrillar envelope of which the axial cords of the rays and arms originate (Pl. Vc. fig. 2, A); and one would naturally expect it to be situated at the lowest part of the calyx-tube. This narrows rapidly downwards, and its interior is marked by five vertical ridges corresponding with the radials in position. They are fairly distinct at the level of the section shown in Pl. V. fig. 4; but they become less marked as they proceed downwards, and, being composed of the whiter, less dense network, disappear together with it. They extend upwards to the edge of the cup at the intermuscular notches; though they are much less distinct on some of the radials than on the others. They thus occupy the position of the ventral radial furrows which are often so marked on the interior of the central funnel of the calyx in other Crinoids (Pl. X. figs. 1, 4, *vrf*; Pl. XII. fig. 15; Pl. XX. fig. 8; Pl. XXX. fig. 3).

From the facts detailed above, we may, I think, assume with tolerable certainty that the tubular body-chamber of *Holopus* is not composed of a "pièce centro-dorsale sessile" as stated by de Loriol;[2] but that it consists of basals and radials like the calyx of any other Crinoid. I cannot quite make out whether de Loriol employs the word "centro-

[1] *Loc. cit.*, p. 407.

[2] Paléont. Franç., *loc. cit.*, p. 188.

dorsal" in the sense in which it is usually understood, *i.e.*, as the cirrus-bearing top stem-joint of the Comatulæ. The tubular body-chamber of *Holopus* is, however, distinctly not of this nature; so that the use of the name "centro-dorsal" is apt to lead to confusion. In a subsequent passage[1] de Loriol expresses another view of the composition of this cup or "cupule." He speaks of the axillaries which are articulated to its upper edge as "radiales uniques," resting as in *Cyathidium*, "sur les angles de la cupule, qui pourrait donc être evisagée comme étant composée de cinq pièces basales interradiales." This would be a most singular morphological condition, and one without a parallel in any other Crinoid. Primary radials would be in contact with each other, but not united, and rest on articular surfaces each of which would be formed by the upper edges of two basals.

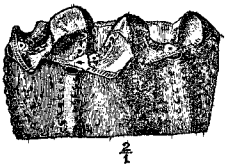
The union between basals and radials is invariably a simple synostosis such as I have described above (pp. 2, 3), and never a muscular joint like that between the upper edge of the calyx-tube of *Holopus* and the compound axillaries. The evidence afforded by sections of the cup, however, indicates clearly that it is principally composed of closely united first radials which, as will be pointed out subsequently, have a remarkable similarity to the radials of the Liassic genus *Eudesicrinus*.

Sir Wyville Thomson thought it probable that second radials are also present in the cup. If so, they must be united to the first by synostosis, which would be a most unusual condition in any Neocrinoid; and the close resemblance of *Holopus* to *Eudesicrinus* seems to negative this idea altogether; while, as pointed out by Sir Wyville,[2] there would be a true muscular joint between the second radials and the radial axillaries, which is not the case in any other recent Crinoid.

Considering then the articular surfaces at the edge of the calyx tube as those of first radials, we find that they differ considerably in size. According to Sir Wyville Thomson[3] "the upper border of the cup, bearing the facets, is very irregular in thickness; and in all the specimens which I have seen, including d'Orbigny's, one side of the border is much thicker and considerably higher than the other side, and the three arms articulated to it are much larger than those articulated to the opposite side. There is thus a very marked division into "bivium" and "trivium," and consequently a bilateral symmetry underlies the radiated arrangement of the antimeres." This is shown in Pl. V. fig. 1, and also, though less clearly, in Pl. III. fig. 1. Besides this again the individual facets, both of bivium and trivium, are of different sizes and shapes. The articular ridge which crosses the central facet of the trivium is considerably longer than that of either of the two remaining facets, and these are longer than the ridges on both the bivial facets. The adjacent muscular plates of these two last are fused into a short tongue-shaped process which stands up prominently in the angle of the bivium. It is essentially of the same nature as the "clavicular piece" which projects in the middle of the distal

[1] Paléont. Franç., *loc. cit.*, p. 191. [2] *Loc. cit.*, pp. 407, 408. [3] *Loc. cit.*, p. 408.

face of every axillary, radial or otherwise (Pl. III. fig. 4; Pl. XXI. fig. 1*c*). A similar but larger process is formed by the fusion of the remaining muscular plate of one of the bivial facets with its fellow on the adjacent facet of the trivium (woodcut, fig. 10). This is seen in the lower part of Pl. V. fig. 1; and it is also visible projecting into the cavity of the calyx in the corresponding part of fig. 2. The other projection seen to the west of it in the same figure is formed by the united muscle-plates of two of the trivial facets, which extend inwards in a more horizontal direction than the larger processes already described.[1] These two large projections are also seen in the north-east portion of fig. 1 on Pl. III., which likewise shows very clearly the separation of the two bivial facets by a pointed upward extension of the outer surface of the calyx. This is very evident in Pl. I. fig. 1, and in the right hand figure on Pl. II. The latter on its left hand side shows traces of the same condition between the other angle of the bivium and the trivial facet next it. This is also visible on the left of Pl. III. fig. 2. But it is much less distinct in the large specimen represented on Pl. I. In the young individual shown in Pl. IV. this character is fairly well marked, except at the two angles of the trivium; while in the still younger and very remarkable specimen obtained by the "Blake" (Pl. V. figs. 9, 10), the shallow calyx is much more symmetrical, and its outer surface sends a pointed extension upwards between every two facets.



$\frac{2}{1}$

FIG. 10.—View of the upper part of the calyx-tube of *Holopus rangi* on its lower or bivial side. The two bivial facets are well shown, together with the interradial process separating them. The left hand one is separated from the adjacent trivial facet by a still larger process; but there is only a small one on the right side.

This surface is marked by an irregular row of scattered tubercles, though none are visible in the other young specimen (Pl. IV.). They are replaced, however, by tolerably well defined ridges which occupy the middle line of the radials, and extend downwards from their upper border to a little distance from the spreading base. They diminish as they go, and finally disappear altogether at a level which probably marks the downward limit of the radials. They are naturally more distinct on the trivial than on the bivial side, and are better marked on the united second and axillary radials, where they bifurcate and are continued outwards on to the arms as well defined medio-dorsal ridges. The lower joints, especially of the trivial arms, also bear one or two small tubercular elevations on either side of the median ridge. These median ridges likewise appear on the second and third radials of the youngest specimen, in which, however, they have more the appearance of a partially disconnected line of tubercles (Pl. V. figs. 9, 10). A row of ill defined tubercles is also visible immediately inside each lateral edge of the second radials. There is a good deal of difference in the external ornamentation on the calyx-tube of the two adult individuals. The large American specimen

[1] Both these figures, as well as the remaining ones on the plate, and in fact all those drawn for Sir Wyville Thomson, are reversed, having been drawn upon the stone in the natural position of the specimens.

(Pl. I.) is almost bare, though faint elevations are visible along the middle lines of the radials, and indistinct, scattered tubercles appear between them, except in the centre of the trivium. In the smaller specimen, however (Pl. II.), there are three, fairly distinct double rows of blunt tubercles which correspond to the trivial radials. But on the bivial side there is more indication of median ridges; while in the fragment shown in woodcut (fig. 10) the double row of tubercles is tolerably distinct all round the cup, except on one of the bivial radials. Other tubercles are scattered about between these rows, though without any definite arrangement; while they are abundant on the dorsal surfaces of the two outer radials and of the large lower arm-joints (Pl. III. figs. 3–9), disappearing, however, as the joints become more and more compressed laterally.

All the entire specimens of *Holopus* which are known to science have been preserved in the dry state, and have a blackish-green tint which is due to pentacrinin, as stated above (*ante*, p. 129). It is darkest in the older individuals, and contributes to the shagreen-like appearance that is so characteristic of the type. An isolated ray (Pl. Va. fig. 3; Pl. Vb. figs. 4, 5) was, however, obtained by the "Blake" off Montserrat, and preserved in spirit. In this condition the skeleton has a dead white appearance.

In the figure of d'Orbigny's original specimen the first radials are shown to bear large, pentagonal axillaries which appear to be all in one piece. They were so described by Pourtalès,[1] and also by Sir Wyville Thomson,[2] who did not, however, exclude the possibility that they might be formed of the second and third radials coalesced, with the syzygy between them obliterated. The very young individual dredged by the "Blake," and the somewhat older form, shown in Pl. IV., throw much light upon this question. The calyx-tube of the former (Pl. V. figs. 9, 10) is wide and shallow, while the second radials which it supports are widely hexagonal and only partially in contact laterally. Resting upon their distal edges are the smaller triangular plates to which I have referred as the axillaries. Agassiz, in his brief description of this remarkable form,[3] states that the larger hexagonal plates are "the radial axillaries of Sir Wyville Thomson, but the smaller triangular ones seem to become fused with them in the adult." I think, however, that there can be little doubt that the larger plates are second radials, and the triangular ones the third or axillary radials. They are all equal and similar, and meet one another all round so as to completely close the cavity of the calyx. It might be suggested that these are the combined second and axillary radials, while the hexagonal plates are the first radials, and no others are present. I do not think, however, that this can be the case; partly on account of the very marked manner in which the hexagonal plates are separated from one another and from the shallow cup below them; and partly because there is no indication whatever of their sending upward extensions between the

[1] *Mem. Mus. Comp. Zoöl.*, vol. iv. No. 8, p. 62, 1878.
[2] *Loc. cit.*, p. 408.
[3] Description of a young *Holopus*, *Bull. Mus. Comp. Zoöl.*, vol. v. p. 213, 1879.

axillaries, like those visible in the next youngest specimen (Pl. IV.); whereas the hexagonal plates themselves are separated in this manner.

Further, in nearly all Neocrinoids which have ten or more arms there are three radials. This is true of all the recent Crinoids except *Metacrinus*, which has a larger number, four or six; and the only fossil genus which has two radials is the aberrant form *Plicatocrinus*.

In all the Neocrinoids, except de Loriol's recently established genus *Eudesicrinus*, there is either a syzygy or a ligamentous articulation between the two outer radials; and the existence of a syzygy in *Holopus* is therefore nothing unusual, though there is less evidence of its presence in the adult condition than is usually the case. But this is scarcely surprising when we remember the excessively intimate union of the first radials, of which no indication whatever is visible on the exterior of the calyx. Some individuals, however, exhibit distinct traces of a sutural line dividing the large axillary into two parts. Such a line is visible in the young specimen (Pl. IV.) on all the axillaries of the trivium, crossing them at the point where the medio-dorsal ridge bifurcates as described above;[1] but it is less distinct in the two bivial axillaries. On the other hand, the three trivial axillaries of the large American specimen present no indications whatever of being composite joints, and have a regular, broadly pentagonal shape. This is well shown in Pl. I. fig. 2; but the bivial axillaries represented in fig. 1 are of an entirely different character, each of them being distinctly in two parts, which look as if they were articulated rather than suturally united, while they do not present the symmetrical appearance characteristic of the corresponding parts in other Crinoids.

In the one case there is a large and wedge-shaped second radial which has all the appearance of an ordinary brachial. It supports a triangular axillary, but the apposed faces of the two do not correspond exactly. The axillary extends beyond the narrower end of the second radial, and so comes in contact with the upward extension of the first radial already described. This is shown in Pl. I. fig. 1. The broader end of the second radial, however, extends considerably beyond the axillary, and meets not only the composite axillary of the adjacent trivial ray, but also the first brachial of its own ray as well as that of the next.

The second radial of the other bivial ray, which is shown in the middle of Pl. I. fig. 1, is more oblong than its fellow. Like it, however, it is wider than the roughly triangular axillary, and supports a considerable portion of the large first brachial. But it is not overlapped by the axillary at the other end, and completely cuts it off from the first radial below.

None of the four remaining axillaries of the specimen figured in Pl. II. show any distinct traces of their being of a composite character;[2] though there are some lines upon

[1] These lines are not clearly seen in the positions of the specimen which are represented on Pl. IV.

[2] The lower angle of one of these exhibits an accidental fracture.

one or two of them which may perhaps admit of this interpretation. But not even this can be said of the originals of figs. 3 and 4 on Pl. III. I think, however, that the evidence detailed above is sufficient to bear out the statement that *Holopus* has three radials, of which the two outer ones are united by syzygy. We should accordingly expect to find a similar syzygial union between the first and second brachials; but of this there is no evidence whatever. The distal face of the first and the proximal face of the second brachial (Pl. III. figs. 3, 7) present the ordinary characters of a muscular joint. There are, indeed, in the small specimen shown in Pl. IV. some traces of lines crossing the first brachials, which might be taken as indicating a syzygial union of two primitive joints; but they are nothing like as distinct as those in the radials. I think, therefore, that for the present, at any rate, we must regard *Holopus* as an exception to the general rule which holds good in other Crinoids, as to the similarity between the modes of union of the two outer radials and the two lower brachials respectively (*ante*, p. 49). It is further remarkable from the fact that there seem to be no syzygies between any of the other arm-joints.

The outer surfaces of the composite radial axillaries were described by Sir Wyville Thomson[1] as "very gibbous, thrown out into almost hemispherical projections, studded with low tubercles" (Pl. III. figs. 3–5). They are produced dorsally a considerable distance beyond the edges of the articular faces, as is the case with all the lower arm-joints (Pl. III. figs. 6–13); and they fit very closely against their fellows, their sides being flattened and more or less marked by ridges and furrows, which interlock with those on the adjacent axillaries. These furrows are also apparent on the sides of the lower arm-joints (Pl. II.; Pl. III. figs. 6–12; Pl. Va. fig. 3; Pl. Vb. fig. 4). The muscle-plates of the axillaries, and in a less degree also those of the arm-joints, are greatly thickened, and their upper edges are cut out into coarse teeth. This is well shown in the right-hand figure on Pl. II. and in the upper part of Pl. III. fig. 2, where some of the adjacent axillaries are seen interlocking with each other.

In all the specimens of *Holopus* yet known, including the fresh fragment dredged by the "Blake" off Montserrat, the arms are strongly recurved, and by their close mutual apposition conceal the disk entirely (Pls. I., II., IV.; Pl. Va. fig. 3; Pl. Vb. figs. 4, 5). Obviously, however, this cannot be the natural condition of the living animal. There is a large food-groove on the upper surface of each arm and pinnule (Pl. Va. fig. 1; Pl. Vb. figs. 1, 4, 5); and there is every reason to think that the living animal, when undisturbed, spreads out its arms with the ventral surface upwards just as other Crinoids do for the purpose of obtaining food. The large size of the paired flexor muscles uniting the joints (Pl. Vb. fig. 1, *m*) would seem to give the power of rolling in the arms very rapidly and completely, so as to afford the utmost protection to the soft parts contained within the cup; while the small, but very close and compact bundles of elastic

[1] *Loc. cit.*, p. 408.

ligaments on the dorsal side of the articular ridges would help in the extension of the arms again.

It has already been mentioned that the trivial arms are larger and better developed than those of the bivium; but in both cases a variable number of the lower joints (Pl. III. figs. 6–13) are considerably larger than those which follow them (figs. 14, 15), and the passage from one to the other is usually somewhat sudden. On the trivial arms there are generally from 8 to 10 of these large, massive joints; but on the bivium there are only about seven, six, or even less. The difference between the two is very well shown in the small specimen represented in Pl. IV. The shape of these lower arm-joints is rather variable. They may be roughly oblong as is the case with the first two or three, or their edges may be more oblique so as to give them a truncated wedge-like form. The more wedge-shaped these joints are owing to the obliquity of their terminal faces, the greater is the inequality in the size of the muscle-plates on the two sides of the median groove. This inequality is visible in the joints represented in Pl. III. figs. 10 to 12, though it is sometimes still more distinct. The pinnule-socket of such a joint is on the thickened upper edge of the higher muscle-plate. The general character of these lower arm-joints is much less regular and symmetrical than is the case in other Crinoids, so that many of them are more or less of a monstrous nature. In some few cases, indeed, the joint is smaller than usual and triangular, not extending completely across the arm, so that the joints above and below it come into contact with one another. This is shown in various parts of both figures on Pl. I.; and it is comparable to the condition of other parts of the same specimen, viz., the way in which the first brachials may partly rest on the second radials, or the axillaries on the first radials, as has been already described.

Sometimes again, a first brachial becomes unusually large, as is shown on two of the bivial arms in Pl. I. fig. 1. The inner one of the two bears a small, triangular, second brachial, and consequently comes into contact with a similarly large, third brachial along its outer edge; but the outer edge of the other second brachial sends a long process forward by the side of the next three joints, which are much smaller than their fellows of the adjacent arm.

Other irregularities of growth appear in the same individual, but they are by no means so marked in that shown in Pl. II. This, moreover, shows very well the rather sudden diminution in the size of the arm-joints which lose their tubercles and gradually become laterally compressed, so that their medio-dorsal edge is tolerably sharp. This form of joint is figured in Pl. III. figs. 14, 15, and Pl. Vc. fig. 2. The longest arms seem to have about eighteen of them, raising the total number of brachials to between twenty-five and thirty.

The larger, outer sides of all the brachials bear the pinnules (Pls. II., Va., Vb,). That of the first brachial is comparatively small, and is attached close to the distal edge of the joint; the next pinnule is invisible in all the specimens, but those of the third

and following brachials are much larger and have broad lower joints that gradually come to take up more and more of the whole surface of the arm-joints to which they are attached. In fact the bases of the pinnules of alternate joints that are borne upon the same side of the arm are only just separated from one another by the narrow ends of the intervening joints, which have their pinnules on the opposite side of the arm. This is well shown in the right-hand figure on Pl. II., and also in Pl. Va. fig. 3. The pinnules are rolled in upon themselves (Pl. III. fig. 16) exactly in the same way that the arms are (Pl. Va. figs. 1, 2). The four or five lower joints are very broad, but the rest of the pinnule tapers away rather rapidly. The joints are united by paired muscular bundles (Pl. Vc. fig. 2, *m*), which is a somewhat unusual condition.

The disk of *Holopus* is unfortunately still but very imperfectly known, and I have only been able to examine it in one specimen. The central mouth is protected by five large and triangular oral plates which are opposite to the clavicular pieces of the united radials (Pl. III. fig. 2). The lateral edges of each of these plates are thickened and sometimes more or less cut into false teeth; while the raised central portion is pierced by from fifteen to twenty minute holes, the water-pores. The bases of the orals seem sometimes to rest directly against the edge of the radials; while they are sometimes separated from this edge by an irregular row of small triangular plates. It is not unlikely that an anal tube is concealed somewhere or other among these plates, as in the case of *Hyocrinus* (Pl. VI. figs. 3, 4); but I have seen no certain traces of it in the dry specimen. The same would probably be the case with *Hyocrinus* under similar conditions.

The food-grooves which come away from the mouth between every two of the oral plates are continued out on to the axillaries and from thence on to the arms. They occupy the deep channel between the large muscular processes at the sides of the joints, and in the dry specimen appear to be bordered by small, irregular plates. These, however, do not seem to correspond either to the side plates or to the covering plates of other Crinoids (Pl. Vc. figs. 9, 10; Pl. XLIX. figs. 6, 7; Pl. LI. figs. 11, 12; Pl. LIV. figs. 4, 6–9); for an examination of spirit specimens shows that these small plates really belong to the tentacles, which are relatively large and stout (Pl. Va. figs. 1, 2. Pl. Vb. fig. 2; Pl. Vc. figs. 1–3—T). The bases of these tentacles are protected by scale-like plates formed of the usual calcareous reticulation (Pl. Vb. figs. 2, 3). They are not easily made out at the side of the arm-groove, but on the lower parts of the pinnules there seem to be from two to three tentacles on either side of each joint. It is difficult to get a correct estimate of their absolute size; but after careful comparison with an eyepiece micrometer I should judge them to be nearly twice the size of the largest that I could find in any preparations of *Antedon eschrichti*. The general arrangement of the tentacles is the same as in other Crinoids; but the epithelial layer covering them is, if anything, thinner than in *Antedon eschrichti*, though thrown into much stronger corrugations at the outer ends of the tentacles.

Shortly before his death Sir Wyville Thomson placed in my hands a portion of the ray represented in Pl. Vb., with the request that I would cut it into sections for him. I found this to be an exceedingly difficult task, partly because of the rolled-up condition of the arms, and partly because the calcareous substance of the skeleton is so much denser than that of other Crinoids; so that the organic basis which is interpenetrated by it and remains behind after decalcification, has nothing like the consistency that we meet with in the corresponding parts of the Comatulæ or of *Bathycrinus*. The presence of large bundles of muscles and ligaments without any helping syzygies also increases the difficulty of all attempts to obtain thin sections. But although I was not so successful as I could have wished, I was able to determine satisfactorily that the anatomy of a *Holopus*-arm is similar in all essential respects to that of an ordinary Crinoid (Pl. Vb. fig. 1; Pl. Vc. figs. 1, 2). The axial cord traversing the central canal of the skeleton gives off its pinnule branches in the usual way, *i.e.*, alternately on opposite sides. These branches have a long distance to go before they reach the pinnules, owing to the attachment of the latter on the upper edges of the large muscle-plates. As long as the branch remains in the substance of the arm-joint it does not take a straight course as is the case in the other Crinoids, but is thrown into a series of loops in a dorsoventral direction (Pl. Vc. fig. 2, *a*), and after it enters the pinnule its course is still somewhat sinuous (Pl. Vc. fig. 3, *a*).

These branches, like the main arm-trunk, are relatively of very small size, which is perhaps to be accounted for by the fixed position of the animal. No swimming movements are of course possible, but only those of flexion and extension are performed by the arms. All the ambulacral structures of the *Holopus*-arm are lodged in the deep median groove of its skeleton, and are usually small in comparison with the great transverse diameter of the joints. The cœliac canal is situated, as usual, between the two large muscular bundles, with a small genital canal separating it from the single subtentacular canal above (Pl. Vb. fig. 1).

The epithelial lining is very much the same in character in all these canals, consisting of low flattened cells. According to Ludwig[1] this is also the case in *Antedon eschrichti*, but this statement is not borne out by his figures. In one figure[2] he represents a well marked cellular lining to the cœliac canal and subtentacular canal, but leaves the genital canal without any; though in a more magnified representation[3] the wall of the genital canal bears an excessively delicate layer of much flattened cells, which consist of little more than nuclei. This is more in accordance with my own observations, for I have always found that the epithelial cells in the genital canal are much flatter and less easy to see than those in the cœliac and subtentacular canals. In *Holopus*, however, the difference is much less marked. The genital cord is of essentially the same nature as in other Crinoids; though it is of a much less branching character in the axillary radial

[1] Crinoiden, *loc. cit.*, p. 29. [2] *Ibid.*, pl. xii. fig. 8. [3] *Ibid.*, pl. xiii. fig. 13.

than is usually the case so near the disk. It is connected with ovaries alternately on opposite sides of the arm, from about the first to the fifteenth brachial (Pl. Vc. fig. 1, *gc.*). The ovaries are short and stout, and confined to the pinnule-bases in the broader, lower parts of the arms; but where the joints are smaller the ovaries appear immediately beneath the water-vessel, and the boundaries between the three arm-canals cannot be traced (Pl. Vc. fig. 2, *ov*). The ova, of which all stages are visible, are more like those of *Antedon eschrichti* than is the case in many Comatulæ, but they are somewhat larger, reaching a diameter of 0·22 mm.; while 0·1737 mm. is the size of the largest ovum of *Antedon eschrichti* which was measured by Ludwig.

I have unfortunately been unable to make out anything definite with regard to the presence of a radial nerve and blood-vessel, which are ordinarily found between the water-vessel and the ciliated epithelium of the food-groove, but this is so often the case in other Crinoids, except in sections of more than average goodness, that I have no doubt whatever respecting the existence of these structures in *Holopus*; and I see no good reason to believe that in any essential point of its visceral anatomy there is any important difference between it and other Crinoids.

All the specimens of *Holopus* which have been preserved in the dry state are of a dull dark green tint, sometimes verging on black. But Mr. Agassiz records that on one occasion, off Montserrat, the "Blake" dredged an imperfect whitish specimen. This consisted of a detached axillary joint and the two arms belonging to it, as shown in Pls. Va. fig. 3, and Vb. fig. 4. The green colour assumed by the dry specimens is possibly due to post-mortem changes, as seems also to be the case in the Pentacrinidæ. Prof. Moseley informs me that many of the individuals dredged by the Challenger were white when captured, although tinged with pentacrinin, owing to the colouring matter being in some way masked during life, and only manifesting itself after death. During a visit which I paid him recently at Oxford, one of the dry specimens of *Holopus* was treated with spirit, and yielded a dull green solution with a red fluorescence.

Prof. Moseley examined it with the spectroscope, and found the colouring matter to be identical with the pentacrinin which he had discovered in the various species of *Pentacrinus* and *Metacrinus* that were dredged by the Challenger in the Pacific and East Indian Archipelago.

Holopus has not yet been met with outside the Caribbean Sea. D'Orbigny's original specimen was obtained at Martinique, while, thanks to Sir Rawson Rawson, others have been discovered in the neighbourhood of Barbados. The young individual figured in Pl. V. was dredged by the "Blake" in 100 fathoms off Bahia Honda; while the white fragment, already mentioned, was found at a depth of 120 fathoms off Montserrat.

During the stay of the Challenger at Bermuda,[1] Sir Wyville Thomson obtained from

[1] The Atlantic, vol. i. p. 321.

a local collector "a small worn and rounded fossil, which seemed to be the cup of a Crinoid allied to *Holopus*."

Prof. Moseley tells me that he thinks it was a recent specimen in the dry state; but since it has unfortunately been lost, I am unable to say anything as to its nature.

B. On the Systematic Position of Holopus.

For some time after the publication of d'Orbigny's original description of *Holopus* the real nature of this remarkable type was more or less misunderstood, partly, perhaps, because the original specimen was tetramerous and not pentamerous like most Crinoids. Eventually, however, Roemer [1] made the genus the type of a new family, Holopocrinidæ; though he did not characterise it more closely. This proceeding was objected to by Quenstedt [2] partly on account of the imperfection of our knowledge of the type, and partly because he considered it possible that *Holopus* might be merely a larval form, destined eventually to become detached and to undergo further transformations. He added "Die Kürze der Säule, die keilförmigen Armglieder mit einfachen Pinnulen sprechen an meisten für die Comatulafamilie." The latter character, however, is absolutely worthless as a generic distinction, many Comatulæ having discoidal or saucer-shaped arm-joints like those of *Pentacrinus* and *Apiocrinus*, while all the Neocrinoids have simple pinnules. The first peculiarity mentioned by Quenstedt is founded on a misapprehension, for he considered the calyx to be formed of the axillary radials only, regarding the tube-like body-chamber as a stem. It exhibits no transverse segmentation, however, and has five articular facets on its upper edge, while it encloses the viscera; and all these characters are totally foreign to the stem of a larval Crinoid, or indeed of any Crinoid whatever.

In the year 1847 a remarkable new type of fossil Crinoid was described under the name of *Cyathidium* by Steenstrup,[3] who spoke of it as like *Eugeniacrinus*, but without a stem. In Theil ii. of the Lethæa Geognostica, Roemer made it the type of a separate family Cyathidiocrinidæ, which he placed next to the Holopocrinidæ; but in Theil v. he refers to it as belonging to the Poteriocrinidæ, together with *Eugeniacrinus* and *Taxocrinus*.

Between *Holopus* and Steenstrup's *Cyathidium* from the Faxoe Chalk there is certainly a very close analogy, though there are a few well marked differences. Apart from the bud-like peculiarities of growth presented by *Cyathidium*, it has a more open cup, with relatively thinner walls than that of *Holopus*. Its appearance varies considerably in different individuals, being sometimes low and shallow, and in other cases longer and more tapering.

The articular facets on its upper edge are much smaller than in *Holopus*, and their downward slope faces inwards instead of outwards, as in the recent form (Pl. III. fig. 1).

[1] Lethæa Geognostica, Theil. ii. pp. 226, 227.

[2] Encriniden, p. 186.

[3] *Amt. Bericht ü. d. 24 Versamml. deutsch. Naturf. und Aerzte in Kiel*, 1846, published 1847, p. 15.

In fact the articular ridge and not the edges of the muscle-plates forms the immediate boundary of the central cavity; and the fossa for the dorsal ligament is still more reduced than in *Holopus*, where it is represented by a median pit that is scarcely to be traced at all in *Cyathidium*. The presence of these articular faces seems to have escaped the notice of de Loriol, which is doubtless due to his not having been able to examine sufficiently good specimens. For he describes the calyx of *Cyathidium*[1] as composed "d'une pièce centro-dorsale cupuliforme portant, sur son bord supérieur, cinq facettes syzygales, sur lesquels reposaient, sans doute, des pièces radiales dont le nombre est inconnu." These supposed syzygial facets are, however, the articular faces of first radials, which are by no means so unknown as de Loriol supposes, though their inferior boundary is still uncertain.

The inner face of each side of the more or less pentagonal cup formed by these radials is marked by a median furrow corresponding to the ventral radial furrow of other Crinoids (Pl. X. figs. 1, 4, *vrf*; Pl. XX. fig. 8), and immediately external to its upper end is the opening of the central canal. These features indicate that in Steenstrup's *Cyathidium* the sides of the pentagonal cup correspond to the radials, just as they do in *Holopus* (Pl. V. figs. 1, 2, 4). To this same genus *Cyathidium*, Schlüter has doubtfully referred a minute Crinoidal calyx discovered by him in the Eocene of Monte Spilecco near Venice.[2] It only reaches 9 mm. in height, but has the same general form as the cup of the recent *Holopus*, being attached by a spreading base, between which and the cup proper there is a more or less well marked constriction. This does not appear to be generally the case in the Faxoe specimens. In one or two cases there seem to be traces of basiradial and interradial sutures, and the position of the former, if real, would indicate that the basals are relatively much higher than they can possibly be in *Holopus*.

The great peculiarity of *Cyathidium spileccense*, however, lies in the relative position of the radials in the pentagonal cup. Their articular surfaces correspond with the angles of the pentagon, and not with its sides, as is the case both in *Holopus* and in Steenstrup's *Cyathidium*, while the middle of each side is raised into a slight ridge which separates the articular facets of two contiguous radials. The result of this is that the five openings of the radial canals are situated at the angles of the calyx. They occupy about the middle of the rim, the outer edge of which is slightly truncated, and shows traces of a fossa for an elastic ligament. The peculiar semilunar shape of these articular facets is considered by Zittel as one of the generic characters of *Cyathidium*. But it certainly does not appear in any of the Faxoe specimens which were lent to Sir Wyville Thomson by Prof. Lovén. We know too little about both of these species to make them types of different genera; and in default of further information it appears undesirable to unite them with *Holopus*. Both forms resemble and differ from it in various points, and are

[1] Paléont. Franç., *loc. cit.*, p. 187.

[2] Astylide Crinoiden, *loc. cit.*, pp. 50–54, Taf. iii. figs. 11–15.

unquestionably very closely allied to it, but I am inclined to think that it would be premature to consider them all as congeneric.

Two other fossil genera of Neocrinoids, *Cotylecrinus* and *Eudesicrinus*, both confined to the Lias, are nearly related to *Holopus* and *Cyathidium*, and should in my opinion be placed in the same family. This has been generally done with *Cotylecrinus*, which is perhaps better known by its older name of *Cotylederma*, Quenstedt. But Schlüter denied its relationship to *Cyathidium*,[1] which had been previously pointed out by Roemer[2] and Deslongschamps,[3] on the ground that there are no perforated plates in *Cotylecrinus*. It is true that Quenstedt's original specimens had no radials attached, and were therefore imperforate, as were most of those figured by Deslongschamps; but the latter author also described and figured a fine specimen of *Cotylecrinus docens*, showing the large articular surfaces of the radials, and the openings of their central canals, just as in *Cyathidium*. This must surely have been overlooked by Schlüter, or he could scarcely have questioned the relationship of the two types.

Both in *Cotylecrinus* and in de Loriol's new genus *Eudesicrinus*, the radials rest upon a more or less tubular structure which is slightly expanded below and has been variously described. In the former genus it has been called a stem by Quenstedt and by MM. Deslongschamps,[4] and a top stem-joint by Schlüter.[5] Zittel[6] suggested that the upper part of it, which is marked by crests with intervening fossæ for the reception of the radials, should be considered as composed of anchylosed basals, and that the lower part is a centro-dorsal? De Loriol,[7] however, considers the whole as a centro-dorsal piece, not having been able to find any trace of sutures separating the upper part from the lower. It is sometimes found in an isolated condition, while in other cases the radials still remain in connection with it, and form a perfectly symmetrical whole, no one of them preponderating in size over the others. They have only been seen in *Cotylecrinus docens*, in which they were first figured by Deslongschamps.

As in *Holopus* and in Steenstrup's *Cyathidium*, they correspond to the sides of the pentagon, and the dorsal fossa is greatly reduced. With regard to the so-called centro-dorsal of *Cotylecrinus*, I am decidedly of opinion that the upper portion on which the radials rest represents the basals. The absence of sutures noted by de Loriol is no proof to the contrary, as we know from the condition of the Palæozoic *Allagecrinus* and *Agassizocrinus*, and of the recent *Rhizocrinus* and *Bathycrinus*.[8] This is in fact tacitly admitted by de Loriol himself in the suggestion that the whole of the calyx tube in *Holopus* and *Cyathidium* consists of anchylosed basals.[9]

If then the so-called cupule of *Cotylecrinus*, instead of being a centro-dorsal as its

[1] *Loc. cit.*, p. 53.
[2] Neues Jahrbuch für Mineralogie, 1857, p. 817.
[3] Mémoire sur la Couche à Leptæna, *Bull. Soc. Linn. de Normandie*, t. iii. p. 181, pl. v. figs. 5, 6.
[4] *Op. cit.*, pp. 174, 179.
[5] *Loc cit.*, p. 53.
[6] Palæontologie, p. 386.
[7] Paléont. Franç., *loc. cit.*, p. 190.
[8] See *Ann. and Mag. Nat. Hist.*, 1883, ser. 5, vol. xi. p. 329.
[9] Paléont. Franç., *loc. cit.*, p. 191.

name implies, really consists, either wholly or partially, of united basals, the composition of the calyx is the same as in *Holopus* and *Cyathidium*, in fact as in most Neocrinoids, few of which are dicyclic. In all cases of which we have full knowledge, the basals rest upon something representing a stem, the special organ which is so characteristic of the Crinoids. It may perhaps be only a central abactinal plate, which becomes transformed into an expanded disk of attachment, as in the Pentacrinoid larva of *Comatula*. But I strongly suspect on general morphological grounds that the basal element in the cup of a Crinoid does not come into direct contact with the supporting surface; and I have an equally strong suspicion that it is never entirely absent. The radials of all Crinoids, excepting the ordinary Comatulæ, rest in fossæ which are separated by interradial ridges that mark the median lines of the united basals (Pl. XX. figs. 2, 3). Such ridges occur in *Cotylecrinus*, the raised angles of the upper edge of the cupule being interradial in position;[1] and I am therefore disposed to agree with Zittel in regarding them as belonging to basals, the lower limits of which are as yet unknown.

There is another character, besides the symmetrical radials, in which *Cotylecrinus* resembles *Cyathidium*. This is the association of two or more individuals in a manner suggestive of a process of budding, both internal and external. Steenstrup noticed this peculiarity in *Cyathidium*, and de Loriol has described it in *Cotylecrinus miliaris*.[2] This last species is further remarkable from the fact that the outer surface both of the cup and of the second radials found associated with it, "est couverte de petites pustules, tantôt un peu écartées, tantôt, au contraire, très serrées." These at once recall the blunt tubercles of *Holopus* (Pls. I., II.).

Cotylecrinus, *Cyathidium*, and *Holopus* are evidently very closely allied, though the two former differ from the latter in the symmetry of their radials.

In the remarkable form, which after having been referred to *Plicatocrinus* and also to *Eugeniacrinus*, has been made the type of a new genus *Eudesicrinus* by de Loriol, there are, however, five asymmetrical radials. These rest "sur une base large, assez élevée, adhérente par un épâtement aux corps soumarins. Cette base n'est point une pièce centro-dorsale semblable à celle des *Cotylecrinus*, renfermant les parties molles de l'animal, c'est un simple support." The radials of this type are much higher than those of *Cotylecrinus*, and enclose a less extensive space in the centre of the funnel which they form by their apposition. It narrows considerably below, however, and I question very much whether it contained more than quite a small portion, if any, of the digestive canal. But according to de Loriol[3] "c'est donc dans la cavité formée par les pièces radiales que se trouvaient logées les parties molles de l'animal." I suspect, however, that the greater part of the visceral mass lay above the surface of the cup, and was protected by the two outer radials and lower arm-joints, just as in *Rhizocrinus* and *Bathycrinus* (Pl. VII. figs. 2, 3; Pl. IX. figs. 1, 3; Pl. X. fig. 20).

[1] Paléont. Franç., *loc. cit.*, pl. 20, figs. 1, 2, 5, 6. [2] *Ibid.*, p. 204, pl. 19, figs. 15, 17. [3] *Ibid.*, p. 98.

With regard to the support beneath the radial pentagon of *Eudesicrinus*, I see no reason for doubting that the upper part consists of united basals. In fact, one of de Loriol's figures[1] shows a distinct horizontal sutural line crossing the middle of the support, and separating the infra-radial portion with interradial crests on its upper surface from the more spreading, attached part below. In another specimen this suture seems to be indicated by an external circular ridge; but the upper face of the support is marked by five petaloid depressions, one of them considerably larger than the rest, which surround a central pit. De Loriol, and, I think, rightly so, regards these depressions as corresponding to the cavities of the chambered organ, the largest being that of the large radial in the trivium. Similar but more regular depressions appear round the middle of the upper surface of the large basal pentagon in *Apiocrinus milleri*, Quenstedt; and they are also shown in de Loriol's figure of *Apiocrinus roissyanus*,[2] while it will be remembered that the chambered organ is invariably in close relation with the basals (Pl. VIIb. figs. 1, 2; Pl. XXIV. figs. 6, 7; Pl. LVIII. figs. 1, 3—*ch*; Pl. LXI.). There can then, I think, be no doubt as to the presence of basals in *Eudesicrinus*, so that the so-called support does not in reality differ essentially from the centro-dorsal of *Cotylecrinus*. The radials, however, are very different in the two cases. Those of *Cotylecrinus* are equal and similar; but in *Eudesicrinus* they are thus described by de Loriol,[3] "Ces pièces sont fort inégales; l'une est notablement plus longue et plus large que les autres, convexe et un peu arquée en dehors, mais d'une manière uniforme; les deux qui la touchent, bien plus courtes et plus étroites qu'elle-même, ne sont guère plus larges, mais plus longues que les deux autres; ces dernières, qui sont les plus courtes et placées vis-à-vis de la plus large, s'arquent en dedans et se coudent un peu vers leur bord supérieur. Dans les échantillons frais la surface externe est couverte de granules épars, écartés, plus ou moins gros et plus ou moins serrés."

Here then we have a type which bears an unusually close resemblance to *Holopus*. The calyx is higher on one side than on the other owing to the inequality of the radials, the central one of the trivium being the largest, while the outer surface, not only of the radials, but also of the arm-joints, is coarsely granular or tubercular. *Eudesicrinus*, however, differs from *Holopus* in one or two minor points. The fossæ on the radials which lodged the dorsal ligaments are larger; and there seems to have been a true muscular joint between the second and the axillary radials, a character presented by no recent Crinoid, and also, so far as I know, by no other fossil species. In *Eugeniacrinus mayalis* from the same horizon the two joints are united by syzygy, just as I believe to be the case in *Holopus*, while the calyx is less coarsely granular. These two species are quite small relatively to *Holopus*, the radials of *Eudesicrinus* not reaching a height of more than 11 mm. Associated with them in the *Leptæna*-bed (Middle to Upper Lias) of Calvados, in Normandy, are some wedge-shaped arm-joints with the muscle-plates on their broad outer sides produced into strong upward processes.[4] These joints have very much the appear-

[1] Paléont. Franç., *loc. cit.*, pl. 29, fig. 7. [2] *Ibid.*, pl. 44, fig. 2, *b*. [3] *Ibid.*, p. 78. [4] *Ibid.*, pl. 11, figs. 1–4.

ance of the more wedge-shaped brachials of a *Holopus*-arm (Pl. III. figs. 10–12), but differ in having the pinnule-socket at the base of the lateral process instead of on its upper edge.

Before the discovery of the support below the radials de Loriol considered *Eudesicrinus* to be a species of *Eugeniacrinus;* and he still regards it as a member of the family Eugeniacrinidæ, to which he has also thought of transferring *Cotylecrinus*, though he has never actually done so. This is partly due to his having been led to regard the calyx-tube of *Holopus* and *Cyathidium* as possibly composed of the five basal pieces only,[1] though there are very serious objections to this view. We know also that the Eugeniacrinidæ, *i.e.*, *Eugeniacrinus, Phyllocrinus,* and *Tetracrinus,* have a jointed stem, which is not the case either in *Eudesicrinus* or in *Cotylecrinus*. Both these genera seem to me to find their proper place in the family Holopidæ, which I should characterise as follows—Basals and radials closely united into a more or less tubular calyx of variable depth. It is sessile and attached by a somewhat spreading base, the foundation of which is probably formed by a dorsocentral plate, like that of *Marsupites*. Ten simple arms, composed of a small number of massive joints.

A. Radials high but asymmetrical, exhibiting a difference of bivium and trivium.
   - *a.* Radials fused together with basals into a tubular body-chamber lodging the viscera. A syzygy between the two outer radials, ... 1. *Holopus.*
   - *β.* Visceral mass was probably lodged above the radials, which are mostly found separated from the subjacent basals and the spreading base of attachment. A muscular joint between the two outer radials, ... 2. *Eudesicrinus.*

B. Radials apparently all alike. Two or more calyces sometimes associated as if budding.
   - *a.* Radials and basals fused into a tubular body-chamber, ... 3. *Cyathidium.*
   - *β.* Radials low, and readily separated from the basals and disk of attachment, . 4. *Cotylecrinus.*

The remarkable Jurassic fossil, described by de Loriol as *Gymnocrinus,*[2] is still too imperfectly known to be placed in this family; but I cannot help suspecting that it is only a portion of the cup of a larger Crinoid. On the other hand, *Micropocrinus gastaldii*, described by Michelin[3] from the Miocene of Superga near Turin, seems to be closely allied to *Holopus*. Michelin's diagnosis runs as follows: "Radix expansa, non ramosa, adhaerens, sublævis; corpus breve crassum, rotundatum, subpentagonale, exterius granulosum, interius profundum, irregulariter vacuum; margine revoluto in decem segmentis acutis subdiviso." I am somewhat puzzled as to the identity of the ten marginal segments. I do not think that they can represent the individual muscle-plates, of which there would be ten in a decalcified calyx; nor does it seem likely that *Micropocrinus* is a ten-rayed type like *Promachocrinus* (*ante*, pp. 37, 38). The real nature of this Crinoid must therefore remain undecided for the present.

On the other hand, the Palæozoic *Edriocrinus*, which has been described by Hall

[1] Paléont. Franç., *loc. cit.*, p. 191.
[2] *Ibid.*, p. 209.
[3] Description d'un nouveau genre de la Famille de Crinoides, *Rev. et Mag. Zool.*, ser. 2, t. iii. p. 93.

from the Upper Silurian of North America, appears to be very closely allied to the recent *Holopus* and to *Cotylecrinus*. According to Meek and Worthen,[1] it seems to differ from this last type "only in having an anal piece on the same range with the first radials, the relations between the two groups being exactly the same as between *Hexacrinus* and *Platycrinus*." These two genera, however, are both Palæocrinoids; but *Belemnocrinus* and *Rhizocrinus*, a Palæocrinoid and a Neocrinoid respectively, are related in precisely the same way. The former, like *Edriocrinus*, has an anal plate in line with the radials; while there is no such structure in *Rhizocrinus* nor in *Cotylecrinus*. The arms of *Edriocrinus* are more numerous than those of *Holopus*, as there are secondary axillaries beyond these in the radial series; but they were rolled in on one another very much after the manner of the *Holopus*-arms; and this was also the case in the Devonian *Lecanocrinus roemeri*, Schultze. The latter type has a stem; but this organ appears to have been altogether absent in *Edriocrinus*, which is thus described by Hall:[2]—"These Crinoids are sessile in the young state, adhering singly or in groups to other substances until fully developed, when they are separated from the foreign bodies, and gradually secreting calcareous matter to cover the cicatrix or point of adhesion, become finally smooth rounded bases." Elsewhere[3] again he described the radial plates as proceeding from this "short pedicle" as from the summit of a column. According to Wachsmuth and Springer[4] this pedicle really consists of five closely anchylosed, basal plates, with the sutures between them obliterated by a secondary calcareous deposit, which eventually removed all traces of the scar denoting the previous attached condition of the individual.

The Mesozoic and recent Holopidæ do not seem ever to have passed into the "free" condition characteristic of *Agassizocrinus* and *Edriocrinus*, so that there is no scar of attachment to be obliterated. But I strongly suspect that the subradial portion of the body, centro-dorsal, support, cupule, or whatever it be called, consists either wholly or (more probably) in great part of anchylosed basals, just as it does in the Palæozoic *Edriocrinus*.[5] For I find it difficult to believe in the existence of a family of Crinoids which are normally devoid of any basal plates, as these are of fundamental importance both in the morphology of the Crinoids, and in that of Echinoderms generally.

Family HYOCRINIDÆ, P. H. Carpenter, 1884.

Genus *Hyocrinus*,[6] Wyville Thomson, 1876.

Definition.—Calyx high, and composed of basals and radials which are nearly equal in length. The former narrow gradually downwards, while the latter are broad and spade-like, each bearing a small undivided arm in the middle of its upper edge. Arm-joints united

[1] Palæontology of Illinois, vol. iii. p. 371.
[2] Natural History of New York, Palæontology, vol. iii. p. 120.
[3] *Ibid.*, p. 143.
[4] Revision, part i. p. 21.
[5] *Ann. and Mag. Nat. Hist.*, ser. 5, vol. xi., 1883, pp. 327–334
[6] Named after Hog Island, one of the Crozets.

by syzygy into groups of two or three, only the terminal joints of which bear pinnules. Lowest pinnules the longest, and the following ones proportionately shorter, so that they all terminate on the same level as the arm-ends. Mouth protected by five large oral plates. Stem composed of short, cylindrical joints with simple or slightly striated faces. Mode of attachment unknown.

A. General Account of the Type.

Hyocrinus bethellianus, Wyville Thomson, 1876 (Pl. Vc. figs. 4–10; Pl. VI.).

Hyocrinus bethellianus, Wyv. Thoms., Journ. Linn. Soc. Lond. (Zool.) (1876), 1878, vol. xiii. p. 51.
Hyocrinus bethellianus, Wyv. Thoms., The Atlantic, 1877, vol. ii. pp. 96–99.

Dimensions.

Total length of calyx and arms (*fide* C. W. T.),	60·00 mm.
Total height of calyx,	7·25 „
Total diameter of calyx,	6·00 „
Height of radial,	4·00 „
Width of radial,	3·00 „
Height of oral plates,	2·75 „
Length of first pinnule,	31·00 „
Diameter of arm-joints,	1·00 „
Greatest height of stem-joints,	1·15 „
Diameter of stem-joints,	1·25 „

The stem is rigid, and consists of short, cylindrical joints, usually a trifle higher than wide, and closely united by thin disks of ligamentous fibres (Pl. Vc. fig. 5, *ls*). The terminal faces of the joints (Pl. Vc. fig. 4) are slightly hollowed, and either plain or marked with indistinct radiating striæ. The opening of the central canal is more or less definitely stellate, and in the substance of each joint itself there is a considerable space (Pl. Vc. fig. 5, *rs*) around the central axis (*ca*). The longest portion of the stem obtained was about 170 mm. in length, but its mode of attachment is not known. Towards the upper end the joints become much shorter, and in the uppermost 5 mm. they are mere disks with a slightly increased width (Pl. VI. fig. 3). The cup, which enlarges gradually upwards, consists of two tiers of very thin plates, the basals and radials, the latter being rather the higher of the two. The basiradial and the five interradial sutures are fairly distinct, but neither in the specimen represented in Pl. VI. nor in a fragment from the same locality, can I make out more than three interbasal sutures. Were it not that this seems to be the case in both specimens, I should be inclined to regard it as unimportant; but under the circumstances I think we must consider that the lower part of the cup consists of two larger pieces and one smaller one, as in certain Palæocrinoids. The small single basal is the one immediately to the right of the anus, *i.e.*, in the interradius beyond the anus to a watch-hand, when the disk is placed upwards. The remainder of

the cup and the arms cannot be better described than in the words of Sir Wyville Thomson.[1] "The second tier consists of five radials, which are thin, broad, and spade-shaped, with a slight blunt ridge running up the centre and ending in a narrow articulating surface for an almost cylindrical first brachial.

"The arms are five in number, they consist of long cylindrical joints deeply grooved within, and intersected by syzygial junctions. The first three joints in each arm consist each of two parts separated by a syzygy; the third joint bears at its distal end an articulating facet from which a pinnule springs. The fourth arm-joint is intersected by two syzygies, and thus consists of three parts; and so do all the succeeding joints; and each joint gives off a pinnule from its distal end, the pinnules arising from either side of the arm alternately. The proximal pinnules are very long, running on nearly to the end of the arm; and the succeeding pinnules are gradually shorter, all of them, however, running out nearly to the end of the arm, so that distally the ends of the five arms and the ends of all the pinnules meet nearly on a level." In all cases the first pinnule is on the left side of the arm. I can say nothing as to the total number of pinnules, the longest arm remaining having six of these appendages on each side. Owing to the large size of the pinnules in comparison with the arms, the epizygal joints to which they are articulated have the appearance rather of axillaries than of ordinary brachials. This is also the case in *Rhizocrinus*, but to a less extent (Pl. IX. figs. 4, 5). But as these appendages are simple and contain the genital glands like the pinnules of other Crinoids, they are undoubtedly of that nature, and must not be regarded as branches of the arms.

The mouth is protected by a very perfect, five-sided pyramid of triangular oral plates, the outer surfaces of which are deeply hollowed along the median line (Pl. VI. figs. 1–4), while the inner surface slopes away rapidly on either side from a strong central keel (Pl. VI. fig. 5). Sir Wyville Thomson described it as marked with deep impressions for the insertion of muscles; but I believe him to have been mistaken in this point. There is no trace whatever of any such muscles being attached to the inner surface of the oral plates in the mutilated specimen represented in fig. 5; while the orals of *Rhizocrinus* and of the Pentacrinoid larva of *Comatula* are certainly not so provided with muscles, and there are no *a priori* reasons whatever for invoking their presence in *Hyocrinus*.

About half the diameter of the disk is occupied by the oral pyramid which covers up the central mouth. Between its base and the edge of the cup there is a pavement of closely set, thin plates belonging to the anambulacral system, which have no regularity either of form or of arrangement. Some of these extend upwards on to the anal tube, which is situated near the edge of the disk in one of the interradial spaces. As in *Rhizocrinus* the oral plates are pierced by the ciliated water-pores which lead downwards into the body-cavity (Pl. Vc. fig. 6, *wp*). But the pores are more numerous than in *Rhizocrinus*, which has only one in each oral plate. In both the specimens of *Hyocrinus* which I have

[1] *Journ. Linn. Soc. Lond.* (Zool.), vol. xiii. p. 52.

examined there are two pores in the oral plate of the anal interradius, and there are no others in any of the anambulacral plates which lie between it and the edges of the radials. The remaining oral plates, however, are not invariably pierced by the water-pores, as pointed out in Chapter VI. (*ante*, p. 95).

The five ambulacra which radiate outwards from the mouth are protected as soon as they have passed through the angles of the oral pyramid by a very complete armour of calcareous plates (Pl. VI. fig. 3). This seems, as in most recent Crinoids, to be less completely differentiated on the arms than on the pinnules. In the wider, basal and middle portions of the pinnules which contain the fusiform genital glands, every pinnule-joint supports two or three quadrate side plates upon each side (Pl. Vc. figs. 9, 10, *sp*). Upon each of the side plates rests one of the covering plates (*cp*), which overlap one another alternately from opposite sides. There are no large side plates, however, in the narrow, proximal portion of the pinnule before the genital cord swells out into the fusiform genital gland; but the covering plates are separated from the pinnule-joints by a number of small irregular plates which belong to the anambulacral system (Pl. Vc. fig. 10). Towards the distal end of the pinnule, on the other hand, the covering plates rest directly upon the edges of the pinnule-joints (Pl. Vc. figs. 8, 9; Pl. VI. fig. 6), as is the case throughout the entire length of the ambulacrum in *Bathycrinus* and *Rhizocrinus* (Pl. VII. fig. 7; Pl. VIII. figs. 4, 5; Pl. IX. figs. 2, 4). They are of a slightly oval shape, and may be as much as 0·6 mm. in diameter.

The genital glands are long and fusiform, and give a swollen appearance to the lower portions of the pinnules (Pl. VI. fig. 1). This lasts for about six or seven of the elongated joints, after which the pinnules taper away slowly to their extremities, while the glands themselves are continued onwards for some little distance as delicate cords which often have a somewhat undulating course, and gradually diminish in size until they are no longer traceable (Pl. Vc. fig. 8, *t*). The axial cord of the skeleton (*a*) is also thrown more or less into curves. The specimen obtained was a male, and the testes have lost all trace of histological structure, as seems to be not unfrequently the case with these glands in other species of Crinoids. They fill up the cavity of the pinnule almost entirely (Pl. Vc. fig. 7, *t*). A reduced cœliac canal (*cc*) with its ciliated cups (*cic*) being visible below the gland in transverse section; while a small subtentacular canal (*stc*) intervenes between it and the water-vessel. The ambulacral nerve and blood-vessel, however, could not be detected, though there can of course be no possible doubt as to their presence.

In one of the fragments[1] which was obtained, the interior of the oral pyramid is exposed (Pl. VI. fig. 5). There is a ring of tentacles around the mouth, and, so far as can be judged from the condition of the specimen, there seem to be four of these on either side of the strong median keel of each oral plate, so that there would be forty in all.

[1] Mr. Black did not see the original of this figure, but simply copied the woodcut, drawn in the first instance by Mr. Wild, which appeared in the *Journ. Linn. Soc. Lond.* Zool.) vol. xiii. p. 54, and subsequently in The Atlantic vol. ii. p. 96.

The mouth leads into a funnel-shaped gullet, the internal epithelial lining of which is raised into strong glandular ridges, as is the case all along the first part of the digestive tract. There is no stomachic dilatation, but the tubular lower portion of the œsophageal funnel is continued into a narrow intestine which forms one simple loop, and turns upwards again to end in the anal opening, as shown in the right hand portion of Pl. VI. fig. 5. The body-cavity is occupied by the usual loose network of connective tissue, with dark brown granules dispersed through it in abundance. It is not strengthened, however, by any of the calcareous rods and plates which are so often found in a similar position in other Crinoids. Careful search also reveals the presence of visceral blood-vessels interpenetrating its meshes; but I have not been able to discover satisfactory evidence of any water-tubes depending from the oral ring into the body-cavity, although these organs must certainly be present, and are probably numerous, like the water-pores on the disk. The colour of the spirit-specimen is a light yellowish-white.

Localities.—Station 106. August 25, 1873; lat. 1° 47′ N., long. 24° 26′ W.; 1850 fathoms; Globigerina ooze; bottom temperature, 36°·6 F. (1°·8 C.). Stem-fragments only (*fide* C. W. T.).

Station 147. December 30, 1873; west of the Crozets; lat. 46° 16′ S., long. 48° 27′ E.; 1600 fathoms; Diatom ooze; bottom temperature, 34°·2 F. (0°·8 C.). "One or two complete specimens and several fragmentary portions" (*fide* C. W. T.).

The stem-fragments from Station 106 seem to have been mislaid; as neither Mr. Murray nor I have been able to find them in the collection of Crinoids which was in Sir Wyville's hands at the time of his death, and was subsequently sent on to me. But the characters of the stem are unmistakable, being utterly different from those of either *Bathycrinus* or *Rhizocrinus;* and unless the fragments in question belonged to a new generic type altogether, which seems improbable, I see no reason for doubting Sir Wyville's identification of them with the *Hyocrinus* which he dredged four months later at Station 147. The point is one of some interest as regards distribution, for Station 106 is in the Mid Atlantic, just north of the Equator, while No. 147 is in the Southern Ocean, 30 miles to the westward of the Crozet group.

The mention of "one or two complete specimens" said to have been obtained at this Station is unfortunately somewhat ambiguous. The original of figs. 1–4 on Pl. VI. seems to have been obtained in a fairly complete condition, lacking, however, the attached portion of the stem; but I am sorry to say that the stem and the head have since parted company. Another stem-fragment was sent me with portions of the thin basals still in connection with its upper end, and also two fragments of the disk, one with four of the oral plates (Pl. VI. fig. 5), and the other with the remaining plate (Pl. Vc. fig. 6). These were mounted in balsam by the late Dr. von Willemoes Suhm, and doubtless belong to the stem-fragment just mentioned, but the greater part of the cup is wanting.

Sir Wyville concluded his first account of *Hyocrinus* by a reference to a specimen

which he provisionally named *Hyocrinus bethellianus?* with the following remarks:—"The last is a beautiful little thing which we dredged from a depth of 2325 fathoms at Station 223, in lat. 5° 31′ N., long. 145° 13′ E., in the east Pacific, with a bottom of Globigerina ooze, and a bottom-temperature of 1°·2 C. It certainly is in many respects very unlike the adult *Hyocrinus bethellianus;* but it may possibly turn out to be the young of that species. There was only one specimen."[1] No reference whatever was made to this type in the description of *Hyocrinus* which was subsequently published in The Atlantic, and is substantially the same as that which appeared in the Journal of the Linnean Society. One would be inclined to conclude from this that the specimen in question was not a young *Hyocrinus* after all; for even though it was obtained in the Pacific, reference would probably have been made to it in Sir Wyville's later account of this very interesting genus. But as the specimen has totally disappeared, and has eluded all Mr. Murray's anxious search, I am naturally unable to say anything about it.

B. On the Systematic Position of Hyocrinus.

Hyocrinus was established by Sir Wyville Thomson in the year 1876,[2] with the remark that "it presents certain general resemblances and even certain correspondences in structure which seem to associate it also with *Rhizocrinus*. There seems little doubt that *Rhizocrinus* finds its nearest known ally in the Chalk and Tertiary *Bourgueticrinus*, and that it must be referred to the neighbourhood of the Apiocrinidæ. Were it not that *Bathycrinus* and *Hyocrinus* are so evidently related to *Rhizocrinus*, the characters of the Apiocrinidæ are so obscure in the two first-named genera that one would certainly have scarcely been inclined to associate them with that group." *Bathycrinus*, though an aberrant form, is far more closely related to *Rhizocrinus* than *Hyocrinus* is. It has the same form of stem-joint and the same absence of pinnules from the arm-bases; while the arm-joints themselves are united in pairs in a very nearly similar manner in both genera. But except in this last point, there is no resemblance between *Rhizocrinus* and *Hyocrinus*. The only known species of the latter genus was said by Sir Wyville Thomson to have "much the appearance, and in some prominent particulars it seems to have very much the structure, of the Palæozoic genus *Platycrinus*, or its subgenus *Dichocrinus*."[3] In fact, Sir Wyville seems to have had considerable hesitation in referring *Hyocrinus* to the Apiocrinidæ; and it was eventually associated by Zittel along with *Plicatocrinus*, in a family Plicatocrinidæ. But the definition which he gave of the family was far from being a satisfactory one, as it stated that basals were absent, which is by no means the case in *Hyocrinus*, and also that there are long, forked arms. Since then, however, he has found that there is an axillary second radial (first brachial, Zittel) in *Plicatocrinus*, which thus

[1] *Journ. Linn. Soc. Lond.* (Zool.), vol. xiii. p. 55. [2] *Ibid.*, p. 48. [3] *Ibid.*, p. 51.

has twelve (ten) arms, instead of five, as in *Hyocrinus*. These arms are composed of short, stiff joints in which no syzygial unions occur; while they bear short pinnules, all of which, except the first four, consist merely of one elongated joint. Zittel further says,[1] "Aus dem Vorhergesagten geht hervor, dass *Hyocrinus* in Bezug auf den Bau der Arme einen differenzirteren Typus darstellt als *Plicatocrinus*. Immerhin aber stimmen beide Gattungen hinsichtlich ihres Kelchbaues besser mit einander überein, als mit irgend einer anderen bis jetzt bekannten Crinoideen-Genus und durften darum wohl derselben Familie zugetheilt bleiben." It appears to me, however, that this supposed resemblance between *Hyocrinus* and *Plicatocrinus* is really very superficial; and that it consists essentially in the condition of the thin and somewhat flattened calyx-plates. This is also the case with the radials of *Bathycrinus*, while the calyces of young Pentacrinidæ have a very considerable similarity to that of *Plicatocrinus*. On the other hand, and apart from the question of basals, the arms of *Plicatocrinus*, as discovered and described by Zittel himself, are utterly and entirely different from those of *Hyocrinus*; and although de Loriol says, "Les analogies tendrent à montrer que les deux genres sont de la même famille,"[2] he concludes as follows, "il faudra peut-être établir une famille pour chacun de ces genres." This I propose to do in the case of *Hyocrinus*, the definition of the family Hyocrinidæ being for the present the same as that given above for the genus.

While resembling *Apiocrinus* and also many Palæocrinoids in the nature of the stem-joints, *Hyocrinus* differs in several respects from the other Neocrinoids. In the first place the apparent presence of only three basals and the small size of the articular facets as compared with the great breadth of the radials, give it a strong resemblance to some of the Palæocrinoids, and more especially to the Platycrinidæ. Although *Hyocrinus* resembles *Platycrinus* in having a symmetrical, tripartite base, the position of the dorsal axis[3] which divides the base symmetrically is not the same in the two genera. If a *Platycrinus* be "orientirt" with the anal interradius posterior, the dorsal axis runs from the right anterior interradius to the left posterior radius; whereas that of *Hyocrinus* (in the only specimen examined) runs from the left anterior radius to the right posterior interradius. But the general form of the calyx, as seen from the side (Pl. VI. fig. 3), is very like that of the Carboniferous *Dichocrinus intermedius*, figured by de Koninck.[4] Its composition, however, is different, as *Dichocrinus* only has two symmetrical basals.

The persistence of the large oral plates is a noteworthy feature of *Hyocrinus*, but it finds a parallel in the Comatulid genus *Thaumatocrinus* (Pl. LVI. fig. 5), and also to a certain extent in *Rhizocrinus*.

[1] Ueber Plicatocrinus, *Sitzungsb. d. II. Cl. k. baier. Akad. d. Wiss.*, 1882, Bd. i. p. 112.

[2] Paléont. Franç., *loc. cit.*, p. 63.

[3] See Beyrich, Ueber die Basis der Crinoidea brachiata, *Monatsber. d. k. preuss. Akad. d. Wiss. Berlin*, 1871, p. 42.

[4] Recherches sur les Crinoïdes du terrain Carbonifère de la Belgique, Bruxelles, 1854, pl. iv. fig. 9.

It is in the character of the arms and pinnules, however, that *Hyocrinus* is most remarkable. The syzygial union of successive pairs of arm-joints is characteristic of *Rhizocrinus;* but in *Hyocrinus* the third and following joints are triple and not double only. A similar difference between the arms of *Heterocrinus simplex* and *Heterocrinus constrictus* has been already noticed.[1]

The arrangement of the pinnules of *Hyocrinus* was described by Sir Wyville Thomson as "hitherto entirely unknown in recent Crinoids, although we have something very close to it in some species of the Palæozoic genera *Poteriocrinus* and *Cyathocrinus*."[2] I do not think, however, that this resemblance is such a very close one after all. For the lateral appendages of the arms of *Hyocrinus*, long as they may be, are true pinnules. *Cyathocrinus*, on the other hand, has no pinnules whatever, but long branching arms, each branch bifurcating several times. It is true that the terminations of all the branches are about on the same level, as is the case with the arms and pinnules of *Hyocrinus*. But in the one genus a bifurcation gives rise to two equal arms which divide again, and in the other there is no bifurcation at all, but the arm-joints bear a series of pinnules which remain perfectly simple throughout their whole length, great though this may be. It has been already pointed out that the nearest approach to the pinnule arrangement of *Hyocrinus* is to be found in *Barycrinus herculeus* from the Carboniferous series of Indiana, United States (*ante*, p. 61). The so-called armlets of this type alternate with one another upon opposite sides of the main arm-trunk and bear no pinnules, so that they seem to correspond somewhat closely with the pinnules of *Hyocrinus*.

The closest approximation among the Neocrinoids to the arrangement of the pinnules which occurs in *Hyocrinus*, though still differing from it in important points, seems to me to be found in the Liassic genus *Extracrinus*. In this curious type each arm consists of a principal trunk bearing pinnules as usual, and giving off at intervals from its inner side a series of smaller armlets which also bear pinnules. The lowest of these are as long as the remaining portion of the arm-trunk from which they spring; and the following ones are of successively diminishing lengths, so that the ends of the original arm-trunk and of its numerous armlets are all on about the same level. In this respect the armlets of *Extracrinus* are comparable to the pinnules of *Hyocrinus;* but they bear pinnules themselves, and only come off from one side of the main arm-trunk, instead of alternating from opposite sides.

There is, therefore, no exact parallel to the condition of the arms of *Hyocrinus* to be found in any Neocrinoid; and remembering this, as well as the peculiarities of the calyx, we cannot say that *Hyocrinus* is specially related to any of the other Neocrinoidea, while it presents important characters which connect it with the Palæocrinoids.

[1] *Ante*, p. 53.

[2] *Journ. Linn. Soc. Lond.* (Zool.), vol. xiii. p. 52.

Family Bourgueticrinidæ, de Loriol, 1882.

Genus *Bathycrinus*, Wyville Thomson, 1872; *emend.* P. H. Carpenter, 1884.

Ilycrinus, Danielssen and Koren, Nyt Mag. f. Naturvidensk., 1877, Bd. xxiii. p. 4.

Definition.—Stem consisting of dicebox-shaped joints and attached by a branching root, the joints above which bear no cirri. The upper part of the stem, immediately beneath the cup, is formed of a large number of thin, discoidal joints. Calyx expanding upwards from the basals, which are closely united into a thickened, discoidal piece without any visible sutures, and but slightly wider than the upper stem-joints. First radials trapezoidal, and united to form a rapidly expanding cup. Second and third (axillary) radials united by trifascial articulation; the muscle-plates of the axillaries produced upwards into strong, wing-like processes. Arm-joints (with the exception of the third, sixth, and ninth) united in pairs by trifascial articulations, only the distal joint of each pair bearing a pinnule, and there are no pinnules on the first few pairs. Interradial areas of the disk naked, paved with loose anambulacral plates, or supported by a single oral plate. Ambulacra have covering plates, but no side plates.

Remarks.—This genus was established by Sir Wyville Thomson in 1872 for a small immature individual which was dredged at the mouth of the Bay of Biscay by the "Porcupine" in 1869 from a depth of 2435 fathoms.[1] But since the discovery by the Challenger of adult examples of two much larger species in the Atlantic and Southern Oceans, the original description of the genus requires modification. One of the Challenger species (*Bathycrinus aldrichianus*) was described by Sir Wyville in the Journal of the Linnean Society for 1876; but in the meantime a fourth species was discovered in the North Atlantic by the Norwegian North Sea Expedition, and it was made the type of a new genus *Ilycrinus* by Danielssen and Koren.[2] For it appeared to them to differ chiefly in size and in the presence of pinnules from *Bathycrinus*, as described by Sir Wyville from the immature "Porcupine" specimen; and his amended account of the genus, founded on the examples dredged by the Challenger, had not reached them in time for reference.

The nearest ally of *Bathycrinus* is undoubtedly *Rhizocrinus*. In fact, without an acquaintance with this genus, one would hesitate to place *Bathycrinus* in the neighbourhood of the Apiocrinidæ at all. There is but a very slight upward expansion of the stem below the head and even in the ring of basals which rests upon it; while the characters of the radials are very different from those of *Rhizocrinus* and *Bourgueticrinus*.

The general character of the dicebox-shaped stem-joints and of the branching root is essentially the same as in *Rhizocrinus*. But the modes in which these joints are

[1] *Proc. Roy. Soc. Edin.*, 1872, vol. vii. p. 772; see also The Depths of the Sea, p. 450.

[2] *Nyt Mag. f. Naturvidensk.*, Bd. xxiii. p. 10.

developed from the thin disks that successively appear immediately beneath the calyx are different in the two genera (*ante*, pp. 26, 27). There is always a large number of these thin joints at the top of the stem of *Bathycrinus* (Pl. VII. figs. 1–3, 11; Pl. VIIIa. fig. 1), whereas in *Rhizocrinus* (Pl. IX. figs. 1–3; Pl. LIII. figs. 7, 8) there are very few, often not more than one or two, and these by no means so thin as in *Bathycrinus*.

An entire stem, or the upper and middle part of one, could therefore be referred without difficulty to its proper genus. But the lower and middle joints are so much alike in the two genera that the proper identification of a fragment or of isolated joints, either recent or fossil, would become a matter of uncertainty, if not of impossibility.

The genus *Bathycrinus* was never formally defined by Sir Wyville Thomson; but in his first account of it[1] he said that, like *Rhizocrinus*, it "must also be referred to the Apiocrinidæ, since the lower portion of the head consists of a gradually expanding funnel-shaped piece, which seems to be composed of coalesced upper stem-joints;" and he nowhere mentioned the presence of any calycular plates below the radials. Subsequently, however, he stated,[2] after examining *Bathycrinus aldrichianus*, that the stem of this genus "barely enlarges at its junction with the cup;" and he described the lower portion of the latter as consisting of a series of basals which are soldered together into a small ring, scarcely to be distinguished from the upper stem-joint (Pl. VII. figs. 1, 2, 11; Pl. VIIa. figs. 12–14; Pl. VIIb. figs. 1, 2).

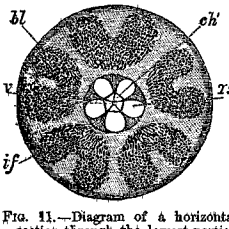


FIG. 11.—Diagram of a horizontal section through the lowest portion of the basal ring of *Bathycrinus aldrichianus*; × 70. *bl*, ligaments uniting the basals to the top stem-joint; *ch'*, the outer vessels in the vascular axis, which are continued downwards from the chambers of the chambered organ; *if*, interradial portions of the fibrillar sheath round the vascular axis which are separated by *rs*; the radial spaces in the upper part of the stem; *v*, central vessel of the vascular axis.

The existence of basals in *Ilycrinus* (*Bathycrinus*) *carpenteri* was also recognised by Danielssen and Koren,[3] who were fortunately able to see the interbasal sutures in young individuals, though these entirely disappear in the adult.

Although invisible on the upper and lower surfaces of the basal ring of *Bathycrinus aldrichianus*, as well as externally (Pl. VIIa. figs. 12–14), the sutures are clearly seen in sections through its middle portion (Pl. VIIb. fig. 2). It expands very slightly from below upwards, and its somewhat hollowed under surface is marked by ten fossæ radiating outwards from the centre and separated by intervening ridges (Pl. VIIa. fig. 14). They correspond to similar fossæ on the upper face of the thin top stem-joint (Pl. VIIa. fig. 3), and lodge five strong but short interradial ligamentous bundles, each having somewhat the form of a horseshoe or V with thick limbs (woodcut, fig. 11, *bl*). These, as already described, unite the basals to the thin, upper stem-joints, and are gradually replaced as the joints become thicker by the two larger bundles which form cushion-like pads between every two of them (*ante*, p. 27; Pl. VIIa. figs. 4–6).

[1] The Depths of the Sea, p. 450.

[2] *Journ. Linn. Soc. Lond.* (Zool.), vol. xiii. (1876) 1878, pp. 48, 50.

[3] *Nyt Mag. f. Naturvidensk.*, Bd. xxiii. pp. 4, 5.

Although in sections through the lower part of the basal ring the limits of its component joints may be traced by the grouping of the five ligaments referred to above, yet the interbasal sutures do not become clearly visible till the level of the lowest part of the chambered organ is reached. Here they appear as actual gaps in the otherwise continuous network of nucleated connective tissue which forms the organic basis of the skeleton, so that in a stained preparation they are shown as five radiating white lines on a coloured ground (Pl. VIIb. fig. 2). They do not, however, reach the outer edge of the section where the connective tissue network forms a complete ring, and this accounts for the absence of any sutural lines upon the exterior of the composite basal piece (Pl. VIIa. fig. 13). The sutural union between this piece and the stem-joints below it appears to be closer than that between the basals and radials, so that the head has a considerable tendency to break away from the stem at the basiradial suture. This was unfortunately the case with one of the two individuals of *Bathycrinus gracilis* which were met with by the "Porcupine's" dredge in 1869, and the head was consequently not brought to the surface. On the other hand, only the head of *Bathycrinus campbellianus* is now known (Pl. VIII. figs. 1, 2. Woodcut, fig. 15 on p. 239), the stem with the basals having separated from it; while Danielssen and Koren figure an isolated head of *Bathycrinus carpenteri* which has lost its basals.[1] But the most remarkable case of this kind was met with at Station 146, in the Southern Ocean, where the dredge must have passed over a small forest of *Bathycrinus aldrichianus*.

About a dozen tolerably perfect individuals were obtained, together with a considerable number of stems retaining the basal ring at their upper ends. This fact is one of no little importance from the light which it throws on the supposed composition of the calyx in the fossil genus *Eugeniacrinus* and its allies *Phyllocrinus* and *Tetracrinus*. These genera are very common in the Jurassic and Lower Cretaceous rocks, especially of the Continent; but by far the greater number of calyces which are met with consist of the radials alone, just like that of *Bathycrinus campbellianus* (Pl. VIII. figs. 1, 2), and the family has accordingly been described as distinguished by the absence of basals. De Loriol[2] says, for example, "Le calice est formé de pièces radiales seulement sans pièces basales." Occasionally, however, a calyx is met with still retaining a portion of the stem attached to it. But no sign of sutures is visible in what appears to be its uppermost joint immediately beneath the radials. This joint, with a portion of the stem attached to it below, is also sometimes met with separate from the radials, as in the case of *Bathycrinus aldrichianus* and *Bathycrinus gracilis*. But the absence of sutures, as shown by the condition of an adult *Bathycrinus*, is no proof that the piece in question does not consist of a ring of closely united basals, a point as to which I have no doubt whatever.[3]

The fibres which effect the synostosis of the basals with the radials above them are

[1] *Nyt Mag. f. Naturvidensk.*, Bd. xxiii. Tab. i. fig. 6.

[2] Paléont. Franç., *loc. cit.*, p. 74.

[3] *Ann. and Mag. Nat. Hist.*, 1883, ser. 5, vol. xi. pp. 327–334.

rather more uniformly distributed over the apposed surfaces of the joints than those uniting the basals to the top of the stem. The upper surface of the basal ring presents five smooth and single sutural fossæ for the attachment of the radials. They slope downwards and outwards from the edge of the central funnel, and each is marked near its outer edge by a single crescentic opening, or by two smaller ones in close proximity (Pl. VIIa. figs. 12, 13). At first sight this more or less double opening would naturally be taken for the termination of the converging right and left forks of two adjacent interradial canals within the basal ring. This apparently obvious explanation is, however, very far from being the true one. The under faces of the radials which rest in these fossæ on the upper surface of the basal ring are marked in the same way by more or less double openings; but these are not the openings of the central canals, as the apparently similar openings are on the under faces of the radials of *Pentacrinus* and *Metacrinus* (Pl. XII. figs. 11, 22; Pl. XX. fig. 9; Pl. L. fig. 5). They are usually quite small and inconspicuous, and not nearly so well defined as the openings of the central canals on the distal faces (Pl. VIIa. fig. 15), with which indeed they have no communication, for they are merely small pits into which portions of the basiradial ligament are inserted; and the same is the case with the corresponding openings in the fossæ on the upper surface of the basal ring (Pl. VIIa. figs. 12, 13). Although the fibres of the basiradial ligament are generally distributed over the whole synosteal surface, they are more especially concentrated in ten bundles which are lodged in ten corresponding pits on each of the apposed surfaces of the basal and radial circlets. Owing to the curvature of these surfaces, these more defined bundles are not shown in the section represented in Pl. VIIb. fig. 3, which passes rather above their level through the general plane of the synostosis; but in the next section they are clearly visible, cut somewhat obliquely as shown in the woodcut (fig. 12, *l*). Both in the woodcut, and in Pl. VIIb. fig. 3, the axial cords (*ai*) are seen to be situated interradially. They retain this position until they reach about half the height of the radial pentagon, where they fork for the first time; and the branches enter the radials by the openings in their lateral faces (Pl. VII. fig. 6*a*). The right branch of one fork and the left branch of its neighbour in the adjoining basal occupy converging canals in the intervening radial, which meet almost directly, so that there is only one opening on the distal face (Pl. VIIa. fig. 15).

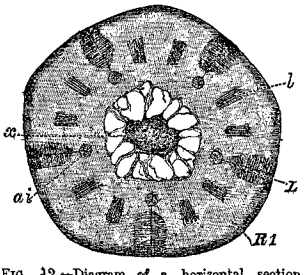


FIG. 12.—Diagram of a horizontal section through the calyx of *Bathycrinus aldrichianus*, at the level of the upper part of the basiradial suture; × 45. *ai*, primary interradial cords; *l*, parts of the basiradial ligament; *L*, interradial ligament uniting *R1*, the first radials; *z*, plexiform gland.

The circular commissure of *Bathycrinus* is thus mainly formed by the actual branches of the primary interradial cords, and not by special interradial commissures uniting these branches as in the Comatulæ and Pentacrinidæ (Pl. XXIV. fig. 9, *cco*). This is also the

case in *Rhizocrinus*, as pointed out by Ludwig;[1] but *Bathycrinus* occupies an intermediate position between *Rhizocrinus* and the types just mentioned, for the two converging cords within each radial are united by an intraradial commissure just as in *Pentacrinus* and *Rhizocrinus* (Pl. VIIIa. fig. 6; Pl. XXIV. fig. 9—*ico*). This does not appear in the section represented in Pl. VIIb. fig. 4, though it is plainly visible in the next one.

The distribution of the axial cords proceeding from the chambered organ of *Bathycrinus* is thus of a very singular character (woodcuts, figs. 13, 14). Each of the five primary

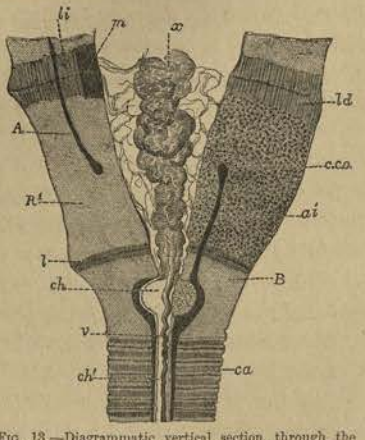


FIG. 13.—Diagrammatic vertical section through the calyx of *Bathycrinus aldrichianus*; × 35. It is interradial on the right side, passing between two of the chambers of the chambered organ, and through the synostosis of two radials (which is shaded darker) so as to show the primary interradial cord (*ai*); while on the left side it passes along the middle line of a ray, and shows the axial cord (*A*) in the distal part of the radial (R^1). *B*, ring of anchylosed basals; *ca*, fibrillar sheath round vascular axis of stem; *ch*, one of the chambers of the quinquelocular organ; *ch'*, its downward extension into the stem; *c.co*, interradial portion of circular commissure; *l*, basiradial ligament; *ld*, dorsal ligament; *li*, interarticular ligament; *m*, muscle; *v*, central vessel of the stem; *x*, plexiform gland.

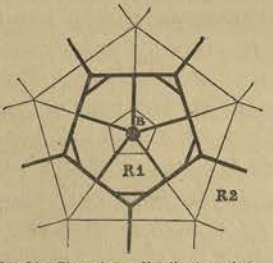


FIG. 14.—Plan of the distribution of the axial cords in the calyx of *Bathycrinus aldrichianus*. *B*, basals; *R*1 *R*2 first and second radials.

interradial cords proceeds upwards close to the central axis of the basal ring (woodcut, fig. 13, *ai*). They pass out of this ring just inside the edge of its central funnel, at the inner ends of the ridges which separate the fossæ lodging the radials and marking the median lines of the basals. For the remainder of their course each of them is contained in the more or less complete canal which is formed by the apposition of two grooves, one on each of two contiguous lateral faces of the radials. These grooves, which run downwards from

[1] *Op. cit.*, *Zeitschr. f. wiss. Zool.*, 1877, Bd. xxix. p. 72.

the openings in the lateral faces of the radials, but close to their inner edges, are well shown in Pl. VII. fig. 6*a*.

As in the Comatulæ, therefore, the circular commissure of *Bathycrinus* (Pl. VIIb. fig. 4, *cco*) is in the innermost part of the radial pentagon, *i.e.*, quite near its centre. There is but a thin layer of limestone between it and the central space, while almost the whole of the fibres forming the interradial ligaments are outside it. The length of these primary interradial cords and their reception in grooves on the apposed surfaces of contiguous radials is very anomalous; and although I detected the true nature of these grooves at first sight, it was nevertheless very long before I could get rid of the notion that the radial openings on the top of the basal ring (Pl. VIIa. figs. 12, 13) were those of the converging branches of the forked interradial canals, as in other Crinoids; and it was not until after some time that I was able to reconcile the apparently conflicting evidence afforded by the study of series of transverse sections on the one hand and of the dissected calyx on the other.

From the facts detailed above, it will be seen that *Bathycrinus* occupies a somewhat anomalous position among Neocrinoids. In *Comatula, Pentacrinus, Apiocrinus,* and *Encrinus* the primary interradial cords fork within the basals; and the adjacent branches of neighbouring forks enter the radials by more or less distinctly double openings on their inner or under faces; but in *Bathycrinus* not only do the cords not fork within the basal ring, but they rise through half the height of the radial pentagon before doing so (woodcuts, fig. 13, *ai;* fig. 14). The nearest approach to this condition is presented by *Rhizocrinus,* though the relative proportions of the plates are exactly the reverse of what we meet with in *Bathycrinus.* In fact, if we make allowance for this difference the condition of *Bathycrinus,* except for the presence of the intraradial commissure, is almost exactly that which was described by Ludwig in *Rhizocrinus;* though, as pointed out already, the real condition of this genus is slightly more normal, *i.e.*, the primary cords fork within the basals, and their converging branches enter the inner ends of the radials as in other Crinoids.

The first radials, which form by their apposition a rapidly expanding cup, have an elongated, trapezoidal outline and rounded outer surface. According to Sir Wyville Thomson,[1] those of *Bathycrinus aldrichianus* are "often free; but in old examples they also are frequently anchylosed into a funnel-shaped piece." In all specimens of this type which I have seen, however, the radials are united laterally, just as in other Crinoids; though they separate more readily than usual when treated with hot alkalies. The ligaments uniting them are close and well defined in the lower part of the funnel (Pl. VIIb. fig. 4, *l*); but in the upper part, *i.e.*, just below the level of the articular surface, there is no interradial ligament (Pl. VIIb. fig. 5), which probably explains the description that has just been quoted from Sir Wyville Thomson. The distal articular faces of the radials

[1] *Journ. Linn. Soc. Lond.* (Zool.), 1876, vol. xiii. p. 50.

are relatively large, but otherwise of the usual character, with paired fossæ for the muscles and interarticular ligaments (Pl. VIIa. fig. 15, *rm'* and *li'*), and the single one beneath the articular ridge for the reception of the dorsal ligament (*ld'*). The second radials (Pl. VII. figs. 5, 5*a*) are broad, flattened, and somewhat quadrate in form, with a more or less distinct medio-dorsal convexity (Pl. VIIb. fig. 6, R2) and a well-marked furrow in the middle line of the ventral surface (Pl. VII. fig. 5*a*). The proximal face resembles that of the first radials, which is high relatively to its width (Pl. VIIa. fig. 15), while the articular surface at the distal end is low and much extended laterally. The axillaries are more or less pentagonal, with a forking median ridge on the flattened dorsal surface. The ventral surface is flattened like that of the second radial, with which the axillaries articulate without the intervention of muscles. But the lateral margins of the median ventral furrow rise gradually from the distal to the proximal end of the joint, where they are produced into more or less expanded, wing-like processes which project forwards over the first brachials (Pl. VII. figs. 4, 4*a*; Pl. VIIa. fig. 17). The bases of these serve for the attachment of the muscles and ligaments which unite the axillaries and first brachials, while their upper portions support the interradial diverticula of the gut (Pl. VIIb. fig. 7, R3).

According to Sir Wyville Thomson, the two outer radials of *Bathycrinus gracilis* and *Bathycrinus aldrichianus* are united by syzygy; while Danielssen and Koren make the same statement respecting *Bathycrinus carpenteri*.[1] This is not really the case, however, and as a matter of fact there are no true syzygies in *Bathycrinus aldrichianus* at all; nor, as I believe, in any species of the genus. The distal face of the second radial is shown in Pl. VIIa. fig. 16. Apart from its external form, it has a general resemblance to the corresponding face of the second radial in *Pentacrinus decorus*, *Pentacrinus naresianus* (Pl. XXX. fig. 1; Pl. XXXIV. fig. 6) and the Comatulæ, *i.e.*, there is a vertical articular ridge which separates the two fossæ lodging large bundles of ligament (*li'*). But in *Bathycrinus* a third and smaller bundle of ligament is inserted into a deep pit (*ld'*) at the lower or dorsal end of the vertical articular ridge. The proximal face of the third radial is of the same character; and in reality the union of these two joints, instead of being an immovable syzygy, is a modification of the bifascial articulation permitting lateral movement only, which is so common in the Comatulæ, and is also characteristic of four recent species of *Pentacrinus*. Externally this form of articulation looks very much like a syzygy, as the joints are brought into closer connection than when they are united by a pair of muscular bundles; but a glance at their apposed faces is sufficient to show that the plainness of the syzygies in *Pentacrinus* or *Rhizocrinus*, and the striation so common in the Comatulæ, are altogether absent, being replaced by distinct ridges and fossæ. In describing *Bathycrinus gracilis*, Sir Wyville Thomson[2] pointed out that "the first brachial is united to the second by a

[1] *Nyt Mag. f. Naturvidensk.*, Bd. xxiii. p. 6.

[2] *Proc. Roy. Soc. Edin.*, 1872, vol. vii. p. 773.

syzygial joint, but after that the syzygies are not repeated, so that there is only one of these peculiar junctions in each arm. . . . And the alternate syzygies in the arms, which form so remarkable a character in *Rhizocrinus*, are absent." He subsequently stated that in *Bathycrinus aldrichianus* "the first and second, and the fourth and fifth brachials are united by syzygies; and after that the syzygies occur sparingly and at irregular intervals along the arms."[1] In like manner Danielssen and Koren[2] described the first two brachials of *Bathycrinus carpenteri* as united by syzygy; a true articulation between the second and third, and also between the third and fourth brachials; while the fourth and the fifth are united by syzygy, the sixth articulated both to the fifth and to the seventh, and the ninth both to the eighth and tenth. After this point muscular articulations and syzygies alternate all along the arms. Owing to the kindness of Dr. Danielssen I have been able to satisfy myself that these "syzygial unions" in the arms of *Bathycrinus carpenteri* are really trifascial articulations like that between the two outer radials of *Bathycrinus aldrichianus*. If, however, this term be substituted for syzygy in the description by Danielssen and Koren, their statements respecting the grouping of the brachials would be perfectly correct, *i.e.*, in the nine lowest brachials there are alternations of a pair of joints united by trifascial articulation and a single joint with muscular articulations at both ends. Beyond the ninth brachial the two forms of articulation alternate with great regularity. Apart from the question of nomenclature, therefore, the Norwegian naturalists were the first who correctly described the grouping of the joints in the arms of *Bathycrinus;* for I find that their description of *Bathycrinus carpenteri* applies both to the little *Bathycrinus gracilis* dredged by the "Porcupine" and to the two Challenger species, *Bathycrinus aldrichianus* (Pl. VII. figs. 1, 2) and *Bathycrinus campbellianus* (Pl. VIII. figs. 1, 3). The non-syzygial nature of the paired unions in the arms of the two last has been determined by actual investigation of the joint faces; while careful microscopic examination of the small individual of *Bathycrinus gracilis* has convinced me that it resembles the other three species in this respect.

The proximal face of the fifth brachial of *Bathycrinus aldrichianus* is shown in Pl. VIIa. fig. 19; and that of a later joint in fig. 20. In both cases the three fossæ are visible around the opening of the central canal; while in Pl. VIIb. fig. 8, the three ligamentous bundles uniting the first and second brachials are seen in section (*li*, *ld*). The same three fossæ (*li'*, *ld'*) appear in Pl. VIIa. fig. 22, which represents a trifascial articular face of *Bathycrinus campbellianus;* while an ordinary muscular joint-face at the proximal end of a brachial is seen in fig. 23.

The presence of this trifascial articulation, and its peculiar grouping, may therefore be considered as distinctive of *Bathycrinus*. Hence the alternation which was referred to by Sir Wyville as so characteristic of *Rhizocrinus* is repeated in *Bathycrinus*, though with two points of difference. In the latter genus the syzygies of *Rhizocrinus* are replaced by

[1] *Journ. Linn. Soc. Lond.* (Zool.), 1876, vol. xiii. p. 50.

[2] *Nyt Mag. f. Naturvidensk.*, Bd. xxiii. pp. 6, 7.

trifascial articulations; while the third, sixth, and ninth brachials are usually free, *i.e.*, united by muscles to the joints before and behind them, as the joints of a Crinoid arm generally are. In *Rhizocrinus*, however, the two joints of each successive pair are united by syzygy, so that muscular articulations and syzygies alternate regularly all along the arm. But as regards the last point *Bathycrinus* approaches *Rhizocrinus* much more closely than was supposed by Sir Wyville Thomson. Instead of there being one syzygy (trifascial articulation) only, or two at the base and others scattered sparingly at irregular intervals, there is just as much regular alternation after the ninth brachial as there is throughout the whole arm of *Rhizocrinus*. In fact, in some irregular arms of *Bathycrinus* the third brachial is the only joint which has muscles attached at both ends, the alternation which would ordinarily commence with the tenth appearing on the fourth and following joints.

Except in *Bathycrinus aldrichianus* the bases of the arms are but little wider than the succeeding portions. The flattening of the dorsal surface at the sides of the median ridge, which commences on the two outer radials, is continued on to the first two or three brachials and then disappears (Pl. VIIb. figs. 7, 8). The same is the case with the sharp lateral edge which is so marked on the second and axillary radials. In *Bathycrinus aldrichianus* it is continued out on to the first eight arm-joints (Pl. VII. fig. 2), and marks the line of junction of the curved dorsal surface and the side faces, which slope upwards and inwards towards the medio-ventral line (Pl. VII. fig. 8). An arm of this species, 30 mm. long, consists of fifty joints; but the first seven or more bear no pinnules. In most cases the first pinnule is borne on the eleventh joint, when this, as is normally the case, has a muscular articulation at its distal end. The ninth brachial is usually a joint of this kind, and in *Bathycrinus aldrichianus* and *Bathycrinus campbellianus* sometimes bears the first pinnule, while the eighth may do so. But the joint which bears a pinnule is invariably united to its successor by muscles, so that the pinnules only occur upon every alternate joint through the whole length of the arm, exactly as in *Rhizocrinus*. The only difference is that the joints which do not bear pinnules are united to those which do by syzygies in *Rhizocrinus*, and by trifascial articulation in *Bathycrinus*. The distal face of a pinnule-bearing joint of *Bathycrinus aldrichianus* is shown in Pl. VIIa. fig. 21; and a corresponding joint-face of *Bathycrinus campbellianus* in fig. 23. In the latter type the pinnule-socket is more at the side of the joint and less at the end than in *Bathycrinus aldrichianus*.

The pinnules of *Bathycrinus* (Pl. VII. fig. 7; Pl. VIII. fig. 5) are moderately short and slender, and composed of relatively few joints. The lateral edges of these joints, especially the outer ones, are produced upwards at the sides of the medio-ventral furrow so as to protect it very completely. This is most marked in *Bathycrinus campbellianus* (Pl. VIII. fig. 5) and to a less degree in *Bathycrinus aldrichianus* (Pl. VII. figs. 2, 7). It is also figured by Danielssen and Koren[1] in *Bathycrinus carpenteri*. The first six or

[1] *Nyt Mag. f. Naturvidensk.*, Bd. xxiii., Tab. i. fig. 14.

eight pinnules which contain the short fusiform genital glands show this feature most distinctly. Somewhat the same character presents itself in the enlarged lower portions of the long pinnules of *Hyocrinus*. But in this case the plate-like sides of the pinnule-joints diverge considerably, so that the median groove is widened instead of narrowed as in *Bathycrinus*. It is therefore partially roofed in by side plates (Pl. Vc. figs. 9, 10), of which there is no trace in *Bathycrinus*. But the plate-like sides of the joints bound a narrow ventral furrow, just as in the arms, and the covering plates rest directly upon their edges (Pl. VII. figs. 7, 8; Pl. VIII. figs. 3, 5), as is the case in *Rhizocrinus* and in the outer parts of the pinnules of *Hyocrinus* (Pl. Vc. fig. 9; Pl. IX. fig. 4; Pl. X. fig. 20). They are continued down the sides of the arm-grooves on to the disk, and in *Bathycrinus aldrichianus*, which has no orals, they stand up all round the edge of the peristome, as is represented, though badly, in Pl. VII. fig. 3. These covering plates are scarcely so substantial as the corresponding plates in *Hyocrinus*, and are also narrower, though nearly as long.

The two lower brachials and part of the third assist in the protection of the visceral mass, the upper surface of which is more or less strongly convex (Pl. VII. fig. 3). There is a very large, funnel-shaped peristomial opening, at the bottom of which is the mouth, and the anus is on a low papilla in one of the five interradial areas. In *Bathycrinus carpenteri* these are supported, according to Danielssen and Koren, by large retiform calcareous plates a little sunk in the perisome, which are obviously persistent orals, though they seem to be entirely absent in the three other species of the genus. In his preliminary description[1] of *Bathycrinus aldrichianus* Sir Wyville Thomson said "the disk is membranous, with scattered calcareous granules. The mouth is subcentral; there are no regular oral plates; but there seems to be a determination of calcareous matter to five interradial points round the mouth, where it forms little irregular calcareous bosses." This description was accompanied by a woodcut which was definitely stated to represent the *Bathycrinus* from Station 106 (in Mid-Atlantic), and not one of the numerous specimens obtained at Stations 146 and 147 in the Southern Ocean. The whole set were at first regarded by Sir Wyville Thomson as belonging to one and the same species, to which he gave the name *Bathycrinus aldrichianus;* but he subsequently limited this name to the individuals from the Southern Ocean. They are figured on Pl. VII., which was lettered and printed off before his death. The disk of one of them is shown on Pl. VII. fig. 3, and obviously bears neither scattered calcareous granules nor interradial bosses round the mouth. This individual has not come into my hands; but the disk of another which I have examined is perfectly naked, except for the covering-plates at the sides of the ambulacra, and the peristome is like that shown in fig. 3. The specimen which was obtained at Station 106, and had been already figured in the Journal of the Linnean Society as *Bathycrinus aldrichianus*, was drawn by Mr. Black for Pl. VIII.; but on one

[1] *Journ. Linn. Soc. Lond.* (Zool.), 1876, vol. xiii. pp. 50, 51; also in The Atlantic, 1877, vol. ii. pp. 92–95, fig. 23.

of the copies of this plate which were sent to me I found the MS. name *Bathycrinus campbellianus* in Sir Wyville's handwriting. He had evidently therefore come to regard this individual as specifically distinct from those subsequently obtained in the Southern Ocean, to which he eventually limited the name *Bathycrinus aldrichianus;* and the disk of this individual (*Bathycrinus campbellianus*) corresponds in most respects with his description quoted above.

The whole of each interradial area is covered with closely set, calcareous plates, not scattered granules; but I cannot make out that they are more abundant in the immediate neighbourhood of the mouth than elsewhere. The covering plates of the ambulacra are smaller and less regular than in *Bathycrinus aldrichianus*, and their course can only be followed with difficulty. In the solitary young specimen of *Bathycrinus gracilis* (Pl. VIIIa. fig. 1) there are neither orals nor anambulacral plates, so that in these respects it resembles the southern *Bathycrinus aldrichianus* rather than the northern *Bathycrinus carpenteri.*

In order that I might be able to compare the anatomy of *Bathycrinus* with that of *Rhizocrinus*, two of the least perfect examples were cut into thin sections with a Leyser's microtome. Unfortunately, however, the circum-oral portions of the one used for the vertical sections were somewhat mutilated, and the remainder was found to be contracted, and, as it were, coagulated by the action of the spirit, so that not even its general anatomy could be made out, much less any histological detail. The arms, on the other hand, yielded more satisfactory results.

In correspondence with the different size of the basals, the chambered organ (Pl. VIIb. figs. 1, 2, *ch*) is more flattened than that of *Rhizocrinus.* It is continued below into the vascular axis of the stem, which is thrown into numerous folds as it passes through the closely packed discoidal joints at the top of the stem. As in *Rhizocrinus* there is only one central vessel (Pl. VIIa. fig. 2; Pl. VIIb. fig. 2—*v*), and not two or more as in some species of *Pentacrinus* and in the Comatulæ. The plexiform gland rising from the chambered organ expands considerably within the central funnel of the calyx (Pl. VIIb. figs. 1, 3–5, *x*), and soon becomes lobulate. It appears to be made up of numerous small cells, which can be traced downwards into the flattened epithelial lining of the vessels in its lower part, and in the chambers of the chambered organ. But it has nothing like the glandular appearance of the corresponding organ in *Antedon carinata*, the numerous lobules of which consist of distinct tubules lined by columnar cells, like those of the urinary tubules.

On its way up through the disk the plexiform gland becomes narrower again, probably on account of its giving off extensions which form the intervisceral vessels, as in other Crinoids. It is interradial in position, as usual, and may be followed at the sides of the fore-gut both in transverse and in longitudinal section (Pl. VIIb. figs. 6–8, *x*) to a little way below the peristome, where its further course cannot be traced. I have little doubt, however, that its connections are essentially the same as in other Crinoids. But owing to

the imperfect condition of the top of the disk in the specimens which were cut, I have been quite unable to make out many details of structure. One point, however, is of interest, and that is that there are more than five water-tubes; for there seem to be three in each interradius, and not one only as in *Rhizocrinus*. As in this genus too, there are strongly marked interradial diverticula of the gut (Pl. VIIb. fig. 7), which are supported by the expanding processes attached to the inner faces of the third radials (Pl. VII. fig. 4*a*; Pl. VIIa. fig. 17).

The arms of *Bathycrinus* present no essential anatomical differences from those of other Crinoids. The food-groove which is sunk within the ventral furrow of the skeleton (Pl. VII. fig. 8; Pl. VIIIa. figs. 4, 5), instead of being some distance above it (Pl. LXI. figs. 4–6), is narrow relatively to the width of the arm, and protected by covering plates, as already described. The radial blood-vessel (Pl. VIIIa. figs. 4, 5, *b*) and ambulacral nerve (*n*) could be clearly distinguished in sections, the latter being exceedingly thin, or apparently sometimes even absent beneath the middle line of the ambulacrum.

Except at the arm-bases the water-vessel (*w*) is relatively small, being much flattened from above downwards; but the tentacles are large and bear numerous papillæ. Beneath the water-vessel, and projecting into the subtentacular canal, so as almost to divide it into two parts, is a more or less continuous band of closely nucleated connective tissue, which perhaps represents the structure marked *x* by Semper[1] in *Actinometra parvicirra* (*Actinometra armata*, Semper, MS.). At the bases of the arms the subtentacular canals are hardly traceable, their places being occupied by a complicated network of genital vessels, which are doubtless connected in the disk with the upper end of the plexiform gland, as in other Crinoids. But this plexus soon passes into a simple genital cord, as represented in Pl. VIIIa. figs. 4, 5, *gc*. It sometimes nearly fills up the small genital canal in which it lies, while there is a large and triangular cœliac canal beneath it (*cc*).

The axial cords of the rays and arms of *Bathycrinus*, like that within the stem, are remarkable for the extensive subdivisions of the branches which proceed from them. Like those within the pinnules of *Holopus* and *Hyocrinus* (Pl. Vc. figs. 2, 3, 8, *a*), they take a somewhat wavy course within the radials, as is seen in Pl. VIIb. fig. 1, A; while the branches which come off from them in the second and third radials are shown in figs. 6, 7, *a'*. Owing to the small height of these joints, the two dorsal branches which are usually so well defined in the Comatulæ (Pl. LXI. fig. 6) extend themselves laterally in the plane of the transverse articular ridge, while they are scarcely visible at all in the arms. On the other hand, the branches which extend upwards towards the ventral surface of the arm subdivide again and again, giving rise to a number of exceedingly fine fibrils, in the course of which bipolar, and occasionally multipolar, cells are clearly to be distinguished (Pl. VIIIa. figs. 4, 5, *a'*). This character is better shown in *Bathycrinus* than in any other Crinoid which I have yet examined.

[1] *Arbeiten aus dem zool.-zootom. Institut in Würzburg*, 1874, Bd. i. p. 261.

The nearest, and in fact the only ally of *Bathycrinus* is *Rhizocrinus;* but the differences between the two genera are much greater than their resemblances. The latter may be summarised as follows:—1. The bifascial union of the stem-joints. This is common to *Bourgueticrinus* and *Mesocrinus*, to the Pentacrinoid larva of *Comatula*, and the Palæozoic *Platycrinus*. 2. The presence of large processes on the second joints above the radials, which support the disk. 3. The absence of pinnules from the lower parts of the arms, and the union of the arm-joints in pairs, with a pinnule on the second joint of each pair only.

The differences between the two types are shown in the following Scheme.

Rhizocrinus.	*Bathycrinus.*
a. May have radicular cirri.	*a.* No radicular cirri.
b. Only one or two discoidal joints at the top of the stem, and those not very thin.	*b.* Many thin discoidal joints at the top of the stem.
c. Basals long; radials short, and very closely united.	*c.* Basals short; radials long, and comparatively free.
d. Primary interradial cords fork within the basals.	*d.* Primary interradial cords fork within the sutures between the radials.
e. Five arms.	*e.* Ten arms.
f. All the joints above the first radials are united in successive pairs by syzygy.	*f.* The fifth, eighth, and eleventh joints above the primary radials have a muscular articulation at each end; the remainder are united in pairs by trifascial articulations.
g. The first pinnule may be either on the primitive sixth or eighth joint above the first radial, *i.e.*, on the epizygal of the third or fourth syzygial pair.	*g.* The first pinnule not lower than the eleventh joint above the first radial.

It has been already pointed out that *Bathycrinus* ranges through a greater number of degrees of latitude than any other Stalked Crinoid, even *Rhizocrinus;* and it is only surpassed in this respect by the ubiquitous *Antedon*. *Bathycrinus carpenteri* was found by the Norwegian North Sea Expedition as far north as 65° 55′ N. lat.; while *Bathycrinus aldrichianus* was twice met with by the Challenger in the Southern Ocean beyond the parallel of 46° S. lat. In the intervening Atlantic Ocean have been found *Bathycrinus gracilis* (Bay of Biscay) and *Bathycrinus campbellianus* (just north of the equator); while other examples of the genus, the specific characters of which are as yet unknown, were dredged by the "Talisman" in the Atlantic (1883) at a depth of from 2000 to 2380 metres (1200 fathoms).[1] It is distinctly an abyssal type, ranging from 1050 to 2435 fathoms. The only Crinoids which have been found at greater depths than the latter are two species of *Antedon*.

We have no certain knowledge of the occurrence of *Bathycrinus* in the fossil state; though it is by no means impossible that some of the stem-joints so common in the

[1] Rapport préliminaire sur l'expédition du "Talisman" dans l'Océan Atlantique, *Comptes rendus*, t. xcvii. p. 1392.

Tertiary beds of the Continent may really belong to this genus. Meneghini has indeed suggested that two forms of joint found in the Italian Tertiaries are those of *Bathycrinus*;[1] but there is no evidence either for or against this idea. For the lower stem-joints of *Bathycrinus* are indistinguishable from the non-cirriferous joints of *Rhizocrinus*, though the differences between the immature joints of the upper part of the stem may be readily recognised in the two genera.

Key to the Species of Bathycrinus herein Described.

I. The lower part of the radial funnel much constricted, ... 1. *Campbellianus.*
II. The radial funnel slopes uniformly downwards from the upper to the lower edge.
  a. Calyx constricted at the basiradial suture. Basal ring scarcely wider above than below. Arm-joints smooth, ... 2. *Aldrichianus.*
  b. The slope of the radials is continued on to the basal ring, which is wider above than below. Arm-joints overlap, ... 3. *Gracilis.*

1. *Bathycrinus campbellianus*, n. sp. (Pl. VIIa. figs. 22, 23; Pl. VIII.; woodcut, fig. 15).

Bathycrinus aldrichianus, Wyv. Thoms. (pars), Journ. Linn. Soc. Lond. (Zool.), (1876), vol. xiii., 1878, pp. 47–51, fig. 1; The Atlantic, 1877, vol. ii. pp. 92–95, fig. 23.

Dimensions.

Total length of specimen, without stem, ...	32·00	mm.
Greatest height of radial funnel, ...	1·80	„
Greatest diameter, ...	3·00	„
Least diameter, ...	0·70	„
Length of second radial, ...	1·85	„
Length of third radial, ...	1·10	„

Stem and basals unknown.

Description of an Individual.—The radial funnel widens slightly from below upwards to just beneath its equator, where it expands considerably, owing to the dorsal surface of the radials suddenly becoming much more convex. The rim of the funnel is thus drawn out into five curved edges in which the second radials rest. They are trapezoidal in form, widen from below upwards, and have a strong medio-dorsal convexity which starts from the whole width of the lower edge and narrows rapidly till just beneath the dorsal edge, whence it is continued on the axillary. The lateral portions of the surfaces of both joints are flattened. The axillaries are shorter than the second radials, but wide and barely pentagonal in form, with a medio-dorsal ridge which forks at its proximal end and is continued on to the arm-bases, where it soon disappears. The flattened lateral portions

[1] Processi Verbali, *Soc. Tosc. di Sci. Nat.*, 7 Luglio 1878, p. xxxii.

of the axillaries have sharp edges, and these are continued along the sides of the first three or four brachials, after which the joints become more cylindrical in form. The two lowest are squarish, and both, but especially the first, are wider than their successors, which are longer than wide, and overlap rather sharply both at the muscular and at the trifascial articulations, but more so at the former.

The first pinnule is almost always on the ninth brachial, and the pinnules are attached some little way behind the distal edges of the joints which bear them, so that the socket is quite distinct from the articular face.

The joints of the six or eight lower pinnules which are enlarged to hold the genital glands have a sharp dorsal edge and broad thin sides which are much produced upwards, but the later pinnules are more slender. The disk is paved with closely set plates.

Colour, in spirit, white.

Locality.—Station 106. August 25, 1873; lat. 1° 47′ N., long. 24° 26′ W.; 1850 fathoms; Globigerina ooze; bottom temperature, 36°·6 F. (1°·8 C.). One specimen, now without stem or basal ring.

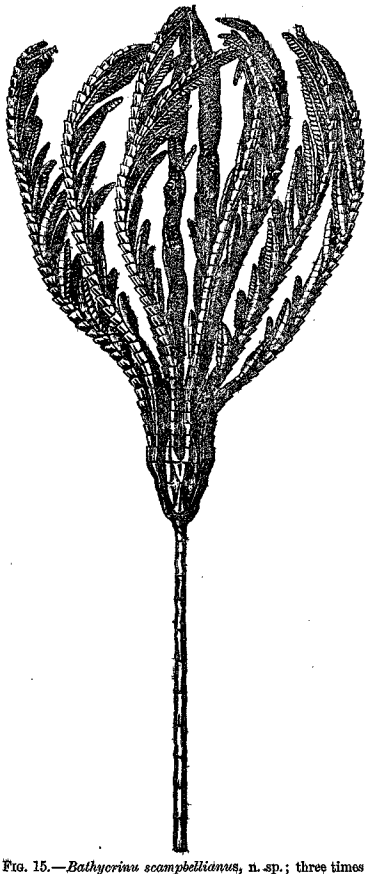


Fig. 15.—*Bathycrinus scampbellianus*, n. sp.; three times the natural size.

Remarks.—This species may be readily distinguished from the other three by the shape of the funnel formed by the united first radials, and the overlap of the arm-joints. As pointed out already (*ante*, p. 234), it was not at first differentiated by Sir Wyville Thomson from the larger form obtained in the Southern Ocean, to which he ultimately limited the name *Bathycrinus aldrichianus*. In fact it seems to be the type from which the description of *Bathycrinus aldrichianus* was mainly drawn up. Although an entire specimen was obtained, the stem appears to have separated from the head and to have been eventually lost; for otherwise we may take it for granted that the stem would have been drawn under Sir Wyville's direction, together with the head belonging to it. In fact the upper part of the stem was drawn, together with the head, for the woodcut (fig. 15) which

appeared in the Journal of the Linnean Society, and also in The Atlantic. There can be no doubt that the head there represented is that of *Bathycrinus campbellianus*, owing to the strongly marked serration of the arm-joints, and the character of the pinnules. In fact the figure given in The Atlantic is definitely stated to represent the specimen from Station 106; while the fragment of a stem which it shows is entirely different from the upper part of the stem of *Bathycrinus aldrichianus* represented in Pl. VII. fig. 11. The numerous thin joints immediately beneath the cup, which are so characteristic of the genus, are not properly represented in the woodcut, and the joints just below where these ought to be are considerably longer than one would expect to find so near the cup. It may be assumed that Mr. Wild's drawing was photographic in its accuracy, so far as he could make out the structure of the small specimen; but errors may have crept in during its reproduction on wood, and the cut was published during Sir Wyville's absence from England, so that he had no opportunity of revising it. Under these circumstances, therefore, it appeared preferable to say nothing about the stem in the specific diagnosis given above, rather than to attempt to describe it from a probably incorrect woodcut.

Two irregularities in the arrangement of the pinnules appear in this specimen. In one case the sixth brachial is not free as it normally is, but is united to the seventh; while the eighth is free instead of the ninth, and bears the first pinnule. In the other case the ninth brachial is not free as usual, but is united to the tenth, which bears a pinnule, so that there are only two free joints, the third and the sixth.

In his first account of the Challenger species of *Bathycrinus*, Sir Wyville Thomson[1] stated that "as the stalked Crinoids are perhaps the most remarkable of all the deep-sea groups, both on account of their extreme rarity and of the special interest of their palæontological relations," he meant "to associate the names of those naval officers who have been chiefly concerned in carrying out the sounding, dredging, and trawling operations with the new species whose discovery is due to the patience and ability with which they have performed their task." In accordance with this idea Sir Wyville established the new species *Hyocrinus bethellianus* and *Bathycrinus aldrichianus;* and he left the MS. names *Bathycrinus campbellianus* and *Pentacrinus naresianus* upon the proofs of two of his plates. These names I have of course adopted. They refer to Lieutenant Lord George Campbell, and to Admiral Sir George Nares, who commanded the Challenger during the earlier part of the cruise.

[1] *Journ. Linn. Soc. Lond.* (Zool.), 1876, vol. xiii. p. 47.

Bathycrinus aldrichianus, Wyville Thomson, 1876 (Pl. VII.; Pl. VIIa. figs. 1–21; Pl. VIIb.; Pl. VIIIa. figs. 4, 5).

Bathycrinus aldrichianus, Wyv. Thoms. (pars), Journ. Linn. Soc. Lond. (Zool.) (1876) 1878, vol. xiii., pp. 47–51; The Atlantic, vol. ii. pp. 92–95, 1877.

Dimensions.

Greatest length of stem (*fide* C. W. T.),	200–250 mm.
Longest stem-joints,	3·50 „
Greatest width of lower joints,	2·00 „
Total length of largest head,	30·00 „
Height of basal ring,	0·80 „
Greatest height of radial funnel,	2·10 „
Greatest diameter of radial funnel,	4·25 „
Least diameter of radial funnel,	1·50 „
Length of second radial,	3·00 „
Length of third radial,	2·75 „

Stem composed of about one hundred joints, of which the first twenty or twenty-five are wider than high, those immediately beneath the cup being mere circular disks, and slightly wider than the thicker ones on which they rest. The next joints below increase slowly in width and more rapidly in length. The ends are slightly expanded and the terminal faces oval-oblong in form. Their shorter diameter is occupied by a strong and continuous transverse ridge, the directions of the ridges on the two faces of any joint being nearly at right angles to one another. About the middle of the stem the diameter begins to increase more rapidly, and the ends of the joints appear less expanded while the terminal faces are circular; and near the base the diameter increases considerably, while the length remains the same or even slightly diminishes. The ends of the joints are considerably expanded and their faces oval, with their longer axes occupied by an articular ridge which is interrupted at the opening of the central canal. The stem ends below in a small branching root.

The basals are closely united into a low, smooth ring, which is scarcely wider above than below, where it is of the same diameter as the thin uppermost stem-joints. On its upper surface rests the funnel-shaped radial pentagon which expands uniformly upwards to its distal edge, so that the calyx has the appearance of being much constricted at the basiradial suture. The surface of each radial is strongly convex in the middle but falls away at the sides, so that the rim of the funnel is drawn out into five curved edges in which the second radials rest. These are trapezoidal in form and convex at their proximal ends. This convexity is continued onwards as a ridge of tolerably uniform width, so that there is a flattened surface on either side of it, which increases in size towards the distal edge. This feature is continued on to the axillaries, which are wider than the second radials, and barely pentagonal in form. The medio-dorsal ridge enlarges

about the centre of the joint, and is continued on to each of the arm-bases, where it disappears after about the first eight joints. These have sharp lateral edges where their flattened sides meet the dorsal surface. The first three or four are wider than long, their successors gradually becoming more cylindrical, but never much longer than wide and not overlapping, so that the dorsal surface is smooth. The third joint is sometimes the only free one, all its successors being united in pairs; while in another case the fourth is free as well as the third, and also the seventh and tenth, the intermediate pairs being united. In a third variety three pairs after the third brachial are united, and the tenth is free again, while the remainder of the arm is normal. There are fifty joints in an arm 30 mm. long (*fide* C. W. T.).

The first pinnule is generally on the ninth, but sometimes not till the eleventh brachial. The pinnule attachment is near the end of the joint, so that the socket enters into the composition of the terminal face (Pl. VIIa. fig. 21). The joints of the lower pinnules are not greatly larger than those of their successors. The disk is unprotected by plates.

Colour, in spirit, white.

About a dozen heads and several stems, some retaining the basals.

Localities.—Station 146. December 29, 1873; lat. 46° 46′ S., long. 45° 31′ E.; 1375 fathoms; Globigerina ooze; bottom temperature 36°·6 F.

Station 147. December 30, 1873; lat. 46° 16′ S., long. 48° 27′ E.; 1600 fathoms; Diatom ooze; bottom temperature 34°·2 F.

I have no record respecting the number of individuals obtained at each Station.

According to Sir Wyville Thomson[1] this species "seems to be widely distributed; we have detected fragments of it at at least six or seven Stations in the Atlantic and the Southern Sea."

Remarks.—The head of this species is readily distinguished from that of *Bathycrinus campbellianus* by the calyx being constricted at the basiradial suture, and not in the radial funnel above it; by the greater width of the arm-bases, and by the smoother dorsal surface of the arms. In the first of these characters it resembles *Bathycrinus carpenteri*, so far as can be made out from Danielssen and Koren's figure; but it is much more robust than the northern species, in which the axillaries are considerably shorter than the second radials, while the lower stem-joints are relatively longer, and have much more expanded ends than those of *Bathycrinus aldrichianus*, in which the dice-box shape is less apparent.

When the collection of Stalked Crinoids came into my hands, I found one bottle labelled "*Pterocrinus* and *Hyocrinus*, Stations 146 and 147." As I had never heard of the former genus, my curiosity was much excited, and it was with considerable disappointment that I found the contents of the bottle, besides *Hyocrinus*, to consist

[1] *Journ. Linn. Soc. Lond.* (Zool.), vol. xiii. p. 51 (1876) 1878.

principally of headless stems of *Bathycrinus aldrichianus*, some with and some without the basal ring at the summit.

Mr. Murray tells me that one specimen of "*Pterocrinus*" was presented to the University Museum at Sydney by Sir Wyville Thomson, which indicates that there must have been several duplicates of the type. The only explanation of these facts which I can think of is, that Sir Wyville had not then (1874) made up his mind that the relatively large individuals dredged at Stations 106, 146, and 147 were generically identical with the small and immature specimen which he had described two years previously as the type of the new genus *Bathycrinus*; so that he was led to give them the MS. name *Pterocrinus*, which he afterwards abandoned (1876) in favour of *Bathycrinus*.

Bathycrinus gracilis, Wyville Thomson, 1872 (Pl. VIIIa. figs. 1–3; woodcut, fig. 16).

1872. *Bathycrinus gracilis*, Wyv. Thoms., Proc. Roy. Soc. Edin., vol. vii. p. 772; The Depths of the Sea, pp. 450–454, fig. 73, 1873.

Dimensions.

Greatest length of stem (about forty joints),	57·00 mm.[1]
Longest stem-joints,	2·50 „
Length of head,	8·00 „

Description of an Individual.—Stem composed of about forty joints, of which the first ten or twelve are wider than high, increasing in thickness from above downwards. The following joints, at first cylindrical, increase rapidly in length, and acquire slightly expanded ends, which become more and more marked in the lower joints, till the width of the end is 1 mm., twice the width of the shaft. The joints diminish in length towards the base of the stem, which ends in a small branching root.

The basals are closely united into a smooth ring, the lower part of which is of the same size as the upper stem-joints, but expands gradually upwards.[2] The radial pentagon above it expands more rapidly, so that there is a constriction at the basiradial suture, though not so marked as in *Bathycrinus aldrichianus*. The radials are strongly convex in the medio-dorsal line, but more flattened at the sides. Second radials nearly oblong, with a sharp median ridge and a slight hollow on either side of it. Axillaries shorter than the second radials and nearly oblong, and also marked by a sharp medio-dorsal ridge which forks about the middle of the joint, and is continued on to the three lowest brachials. There are only about twelve brachials in the arm, all of which are distinctly longer than wide, while the first two or three are scarcely wider than the rest, and have straight lateral edges like the radials. The later joints overlap rather sharply, so that the dorsal edge of the arm is serrate. The disk is unprotected by plates.

Colour, in spirit, brownish-white.

Locality.—H.M.S. "Porcupine," 1869. Station 37. Lat. 47° 38′ N., long. 12° 8′ W.;

[1] Sir Wyville gave this measurement as 90 mm., which was possibly a misprint for 60.

[2] This expansion is not quite marked enough in the figure.

2435 fathoms; Globigerina ooze; bottom temperature 36°·5 F. One nearly complete specimen, and one stem with the basal ring attached, but wanting the rest of the calyx.

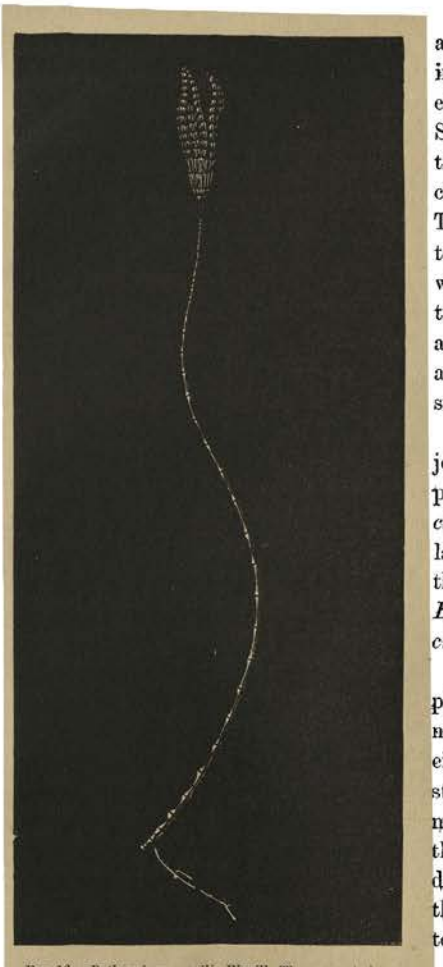


FIG. 16.—*Bathycrinus gracilis*, Wyville Thomson; twice the natural size.

Remarks.—The shortness of the arms and the absence of well grooved pinnules indicate that the single specimen of this elegant little species is not fully developed. Sir Wyville Thomson[1] said that "there is no trace of pinnules, and the arms resemble in character the pinnules of *Rhizocrinus*." There are, however, little stumps on the terminal joints of one or two of the arms which give them the appearance of bifurcation, just as at the growing point of the arms of a young *Comatula* or *Pentacrinus;* and I see no reason to doubt that these stumps are the commencing pinnules.

I have already pointed out that the arm-joints of *Bathycrinus gracilis* are united in pairs exactly like those of *Bathycrinus aldrichianus* and *Rhizocrinus*, except that in the latter genus the union is a syzygial one; and the supposed resemblance of the arms of *Bathycrinus gracilis* to the pinnules of *Rhizocrinus* thus disappears.

As might be expected from its geographical position, *Bathycrinus gracilis* comes nearer to *Bathycrinus carpenteri* than to either of the Challenger species. The lower stem-joints are strongly constricted with markedly expanded ends as in that type; but the absence of orals, the well defined mediodorsal keel on the radials and arm-bases, and the serrate condition of the arms are sufficient to distinguish it without difficulty.

During the expedition of the "Talisman" in 1883[2] a few much mutilated specimens both of *Bathycrinus gracilis* and of *Rhizocrinus rawsoni* (*Democrinus parfaiti*, Perrier)

[1] The Depths of the Sea, p. 452, 1873.

[2] *Comptes rendus*, t. xcvii. p. 1392. See also H. Filhol, Voyage du "Talisman" in *La Nature*, No. 572, 17th May 1884, p. 391.

were obtained off the Morocco coast at a depth of from 2000 to 2300 metres (1200 fathoms), "par le travers du cap Ghir et du cap Noun, à 120 milles environ de la côte." This locality (in about lat. 30° N.) is the only one at which these two genera have been found associated. It is some 18° farther south than the position at which *Bathycrinus gracilis* was first discovered by the "Porcupine."

Genus *Rhizocrinus*, M. Sars, 1864; *emend.*, P. H. Carpenter, 1884.

Eugeniacrinites
Apiocrinites
Asterias } Auctorum.
Goniaster

1846. *Bourgueticrinus*, d'Archiac, Mém. Soc. géol. de France, sér. 2, t. ii. p. 200.
1847. *Conocrinus*, d'Orbigny, Cours élément. de Paléontol. et de Géol. stratigr.,[1] t. ii. Fasc. 1, Paris, 1852, p. 147.
1850. *Bourgueticrinus*, d'Archiac, Mém. Soc. géol. de France, sér. 2, t. iii. p. 418.
1850. *Conocrinus*, d'Orbigny, Prodrome de Paléontologie stratigraphique universelle des Animaux Mollusques et Rayonnées, t. ii., Paris, 1850, p. 332.
1852. *Bourgueticrinus*, Forbes, Monograph of the Echinodermata of the British Tertiaries, p. 36.
1864. *Rhizocrinus*, M. Sars, Forhandl. Vidensk. Selsk., p. 127.
1868. *Bourgueticrinus*, Pourtalès, Bull. Mus. Comp. Zoöl., vol. i., No. 7, p. 128.
1868. *Rhizocrinus*, M. Sars, Mémoires pour servir à la connaissance des Crinoïdes vivants, p. 38.
1868. *Rhizocrinus*, W. B. Carpenter, Proc. Roy. Soc., p. 173.
1872. *Rhizocrinus*, Wyv. Thoms., Proc. Roy. Soc. Edin., vol. xvii. p. 770.
1874. *Rhizocrinus*, Pourtalès, Ill. Cat. Mus. Comp. Zoöl., No. 8, p. 27.
1874. *Rhizocrinus*, Manzoni, Bollett. d. R. Com. Geolog., p. 158.
1874. *Rhizocrinus*, Beyrich, Monatsber. d. k. preuss. Akad. d. Wiss. Berlin, p. 666.
1875. *Conocrinus*, Meneghini, Atti dell. Soc. Tosc. di Sci. Nat., vol. ii. p. 46.
1875. *Rhizocrinus*, Meneghini, *Ibid.*, p. 57.
1878. *Conocrinus*, de Loriol, Monographie des Crinoïdes fossiles de la Suisse, p. 190.
1880. *Conocrinus*, Zittel, Handbuch der Palæontologie, Palæozoologie, Bd. i. p. 391.
1882. *Rhizocrinus*, P. H. Carpenter, Bull. Mus. Comp. Zoöl., vol. ix., No. 4, p. 173.
1883. *Democrinus*, Perrier, Comptes rendus, t. xcvi. p. 456.
1883. *Rhizocrinus*, P. H. Carpenter, Ann. and Mag. Nat. Hist., ser. 5, vol. xi. p. 336, 1883.
1884. *Rhizocrinus*, P. H. Carpenter, Proc. Roy. Soc. Edin., vol. xii. p. 356.

The stem is composed of dice-box shaped joints, and terminates below in a spreading root, or bears a number of branching radicular cirri which come off irregularly, but not in definite verticils.

Only a very few of the upper joints are thin and discoidal, and slightly wider than those below them.

[1] The second volume of the Cours élémentaire bears the date 1852 on the title page; but the genus is referred to as "*Conocrinus*, d'Orb., 1847." This also appears in the Prodrome de Paléontologie published in 1850, in which work according to de Loriol, the genus was first established; and I suspect that the date 1847, which is claimed by d'Orbigny for his genus, merely has reference to an unpublished MS.

The calyx is higher than wide, generally much so. It consists of five basals and five radials, of which the former (in the recent species at least) are much the longer. Arms five, the joints united in pairs by syzygies, with pinnules on the epizygals only. The first pinnule on the epizygal of the third or fourth pair. The epizygal of the first pair has the sides of its ventral furrow produced upwards into strong processes which support the disk. The peristome is protected by five oral plates of variable size, but the remaining portions of the interpalmar areas are not plated. The ambulacra have covering plates, but no side plates.

Remarks.—The name *Rhizocrinus* was first employed in 1864 by the late M. Sars[1] to designate a singular new Crinoid which had been discovered by G. O. Sars in his dredgings among the Lofoten Islands; and it was the extreme interest of this type as a sort of degraded Apiocrinite which, through the intervention of Dr. Carpenter and the late Sir Wyville Thomson, led to the dredging cruise of H.M.S. "Lightning" in 1868. The results of this cruise, *Rhizocrinus* among them, were so remarkable that it was followed by the "Porcupine" Expedition of 1869–70, and eventually by the voyage of the Challenger. It was the discovery of *Rhizocrinus*, therefore, and the interesting speculations to which this discovery gave rise, that led this country to take a foremost place in the work of deep-sea exploration. Meanwhile, however, *Rhizocrinus* had been rediscovered by the late Count Pourtalès during the dredgings carried on by the U.S. Coast Survey in connection with the regular exploration of the Gulf Stream.[2] At that time (May 1868) Sars's elaborate memoir on the type had not yet appeared, and the specimens dredged by Pourtalès were described by him as "undoubtedly belonging to the genus *Bourgueticrinus*, as defined by d'Orbigny," a remark in which I entirely concur. He gave the provisional specific name "*Hotessieri*" to his specimens, thinking that they might possibly be identical with *Bourgueticrinus Hotessieri*, d'Orb., stem-joints of which had been discovered in a recent breccia at Guadeloupe. After the appearance of Sars's memoir, however, he recognised the identity of the Gulf Stream and of the Lofoten examples of the type, for which he adopted Sars's name *Rhizocrinus lofotensis*.[3]

But he took a totally different view of the composition of the cup from that proposed by Sars, and in this respect, as will be pointed out immediately, he was decidedly in the right. For the large subradial portion of the summit, which was considered by Sars as an enlarged upper stem-joint, was shown by Pourtalès to consist of five closely anchylosed basals.

In the year 1875 the name *Rhizocrinus* was doubtfully given by Meneghini[4] to some

[1] *Forhandl. Vidensk. Selsk.*, Christiania, 1864, p. 127. "Den 14de. October, Hr. Sars holdt et Foredrag om Pentacrinoide tilstanden af *Comatula sarsii* og om en ny levende Crinoide *Rhizocrinus lofotensis*."

[2] Contributions to the Fauna of the Gulf Stream at Great Depths, *Bull. Mus. Comp. Zoöl.*, vol. i., No. 7, p. 128.

[3] List of the Crinoids obtained on the coasts of Florida and Cuba by the U.S. Coast Survey Gulf Stream Expeditions, in 1867, 1868, 1869, *Ibid.*, No. 11, p. 357.

[4] I Crinoidi Terziarii, *Atti dell. Soc. Tosc. di Sci. Nat.*, vol. ii. pp. 46, 50.

stem- and arm-joints from the Italian Tertiaries, while he revived d'Orbigny's name *Conocrinus* for d'Archiac's *Bourgueticrinus thorenti*, after an interval of nearly twenty-five years. During this period, so far as I am aware, no palæontologist had taken any notice of d'Orbigny's attempt to differentiate *Conocrinus* from *Bourgueticrinus*. The first description[1] which he gave of the former genus (1847 ?) ran as follows: "C'est un *Bourgueticrinus* ayant la tige comprimée, mais avec une seule série de pièces brachiales, sans pièces basales;" and he referred to it one unnamed species from the Suessonien (Lower Eocene). Three years later (1850) he spoke of *Conocrinus* as "genre voisin des *Bourgueticrinus*, mais sans pièces basales, comme les *Eugeniacrinus;*" and he mentioned *Bourgueticrinus thorenti* of d'Archiac as belonging to this generic type.[2] Meneghini has shown, however, that two species were described under this name by d'Archiac. One is a much elongated type, first described in 1846, and probably that referred to by d'Orbigny in the following year; while the other that was not noticed till 1850, the year in which the second (first ?) description of *Conocrinus* appeared, is the *Eugeniacrinus pyriformis* of Münster. This species was not referred by d'Orbigny to his new genus *Conocrinus*, though undoubtedly belonging to it, as pointed out by Meneghini. But it was retained by him in *Eugeniacrinus*, so that the only species of *Conocrinus* recognised by d'Orbigny was the elongated *Bourgueticrinus thorenti* of d'Archiac. The figures and descriptions of this type given by the latter author are somewhat incomplete. He had very few specimens, and was exceedingly doubtful about the position of the sutural lines, while they are certainly placed wrongly in his figure,[3] according to which the second radials rest upon the sutures of the first. There is likewise no indication of an enlargement of the uppermost stem-joints so as to form a "summit," which is so characteristic of *Bourgueticrinus;* while the presence of basals below the radials or "pièces supérieures" of *Bourgueticrinus thorenti* was distinctly described by d'Archiac, though he probably figured them incorrectly. Nevertheless, *Conocrinus* is a *Bourgueticrinus* without basals, and d'Archiac's species in which basals are present is made the type of the genus!

Neither does it help in the differentiation of the two genera to speak of *Conocrinus* as a *Bourgueticrinus* with a compressed stem, when the stem of *Bourgueticrinus* itself is described as being compressed.[4] I find very considerable difficulty in comprehending what d'Orbigny really meant by *Conocrinus*. If it be "voisin de *Bourgueticrinus*," but also resembles *Eugeniacrinus* in the absence of basals, why was it omitted in his scheme of classification of the Apiocrinidæ, published in 1858, from the fourth section comprising *Eugeniacrinus* alone,[5] and distinguished by having only "une série de pièces au sommet"? On p. 95 he pointed out that no Tertiary species of *Bourgueticrinus* were then known, from which one may infer that the Tertiary fossils previously referred to this genus

[1] Cours élément. de Paléontol. et de Géol. stratigr., t. ii., 1852, p. 147.

[2] Prodrome de Paléontologie stratigraphique universelle des Animaux Mollusques et Rayonnées, t. ii. p. 322.

[3] *Mém. Soc. géol. de France*, ser. 2, t. ii. p. 200, pl. v. fig. 20.

[4] Cours élément. de Paléontol. et de Géol. stratigr., t. ii., 1852, p. 147.

[5] Hist. Nat. des Crinoïdes, p. 2.

really belonged to *Conocrinus*. But as he did not place the latter type among the Apiocrinidæ together with *Bourgueticrinus* and *Eugeniacrinus*, it would seem that he had either abandoned it altogether, or else entirely misunderstood its real character and affinities; and in the absence of figures or original specimens his account of it would be absolutely unintelligible.

Rhizocrinus was first described by Sars in 1864,[1] and more fully in 1868[2]; and though he was led to consider the anchylosed basals as a top stem-joint, this error was corrected by Pourtalès and myself before a fresh diagnosis of *Conocrinus* was given by de Loriol.[3] This indeed was only provisional, in default of better knowledge, and owing to Meneghini's failure to find the interbasal sutures in a section through the lower part of the calyx,[4] just as in a recent *Rhizocrinus* or *Bathycrinus* (Pl. VIIa. fig. 13), de Loriol was led to consider it probable that the basals "n'existent pas et sont intimement soudées, de manière à former comme une seule pièce centro-dorsale." He thus fell into exactly the same error as had been made by Sars and Ludwig respecting the recent *Rhizocrinus lofotensis*. Zittel,[5] however, who had satisfied himself regarding the presence of interbasal sutures in *Conocrinus pyriformis*, recognised the identity of this genus with *Rhizocrinus*, but did not adopt the latter name on the ground that "Nach den Regeln der Priorität gebührt dem Namen *Conocrinus*, d'Orb. die Priorität, wenn gleich die Gattungsdiagnose d'Orbigny's unvollständig und theilweise unrichtig ist."

It seems to me, however, that this is stretching the rules of priority to the widest possible limit, or even beyond it; and that definitions which are incorrect, meaningless, and altogether incomplete have no claim whatever to recognition. Lütken remarked in 1864 that the distinction of *Conocrinus* from *Bourgueticrinus* was still a matter of uncertainty; while d'Orbigny's own countrymen Hébert and Munier-Chalmas did not adopt his generic name for the new type which they described as *Bourgueticrinus suessi*; and although it was subsequently referred by de Loriol to *Conocrinus*, and carefully described, the genus *Rhizocrinus* had meanwhile become thoroughly well established and universally recognised by zoologists.

Both Sars and de Loriol were in error as to the composition of the calyx in this type; and a correct definition of *Conocrinus* was not given until the publication of Zittel's Palæontology in 1879; while even as early as 1868,[6] and subsequently more fully in 1874,[7] Pourtalès had correctly pointed out the characteristic features of Sars's genus *Rhizocrinus*, especially as regards the presence of basals, which had been supposed to be either absent altogether, or else modified into a kind of rosette. According to Sars[8] "Ce qui est remarquable et characteristique pour la tige du *Rhizocrinus*, c'est son sommet

[1] *Forhandl. Vidensk. Selsk.*, p. 127.
[2] Crinoïdes vivants, pp. 38, 39.
[3] Swiss Crinoids, p. 191.
[4] *Loc. cit.*, p. 50.
[5] Palæontologie, p. 392.
[6] *Bull. Mus. Comp. Zoöl.*, vol. i., No. 7, p. 129.
[7] *Ill. Cat. Mus. Comp. Zoöl.*, No. 8, pp. 27, 28.
[8] Crinoïdes vivants, p. 4.

qui forme un grand évasement obconique ou caliciforme, ce qui donne à notre Crinoïde de la ressemblance avec le genres fossiles *Apiocrinus* et *Bourgueticrinus*. Cette extremité n'est donc pas autre chose que le sommet de la tige qui s'élargit successivement." Sars considered the summit therefore as an enlarged uppermost stem-joint analogous to the centro-dorsal of the Comatulæ. He was unable to resolve it into any component parts by treating it with alkalies; and it is consequently not surprising that he was led to regard the whole subradial portion of the calyx as composed of but one single piece. In fact he was never able to separate this piece from the radials or the radials from one another, the existence of these plates being only indicated on the outside of the calyx by very faint sutural lines, occasionally rendered more distinct by slight furrows.

It never seems to have struck him, however, that there might be basal plates below the radials which were similarly, but more closely anchylosed; and he was led to consider the basals as fused, like those of Comatulæ, into a kind of rosette. This circular plate (Pl. VIIIa. figs. 6, 7; Pl. X. figs. 1, 4—*br*) "est située à l'intérieur dans l'espace central laissé en dedans de l'anneau formé par l'adhésion des premiers radiales;"[1] but Sars was unable to isolate it, owing to its very close adherence to the first radials.

It has been pointed out that *Rhizocrinus* was dredged by Pourtalès in 1868 before he had heard of its discovery by Sars; and the condition of his specimens was fortunately such that he was able to describe the calyx as "composed of a cycle of elongated basal (pelvic) pieces, followed by the much shorter first radials (costals) alternating with them. These pieces are all so intimately connected with each other that the sutures are seen with difficulty."[2] This account seems to have escaped the notice of Sir Wyville Thomson; for in his description of the "Porcupine" Crinoids[3] he stated that "in *Rhizocrinus* the basal series of plates of the cup are not distinguishable. They are masked in a closed ring at the top of the stem." He did not, however, entirely accept Sars's view of the composition of the calyx; for he went on to say that "whether the ring be composed of the fused basals alone, or of an upper stem-joint with the basals within it forming a rosette as in the calyx of *Antedon*, is a question which can only be solved by a careful tracing of successive stages of development." The relatively large specimens which were dredged by the "Porcupine" in 862 fathoms off Cape Clear, show the interbasal sutures very clearly; and though they were referred at the time to *Rhizocrinus lofotensis*, they really belong to the Caribbean species *Rhizocrinus rawsoni*, larger specimens of which were obtained by the "Hassler" off Barbados in 1871, and described by Pourtalès in 1874. These, like the "Porcupine" specimens and the Gulf Stream variety of *Rhizocrinus lofotensis*, also showed distinct interbasal sutures. Pourtalès was therefore led to dissent from Sars's description of the calyx in this genus, and to repeat more emphatically his own previous statements concerning the existence of long but closely united basals.[4]

[1] Crinoïdes vivants, p. 12.
[2] *Bull. Mus. Comp. Zoöl.*, vol. i. p. 129.
[3] *Proc. Roy. Soc. Edin.*, vol. vii., 1872, p. 770.
[4] *Mem. Mus. Comp. Zoöl.*, No. 8, pp. 28, 29.

He found all the sutural lines in the calyx of both species, including those between the basals, to be "always plainly visible with a lens of moderate power;" and he was therefore naturally surprised at the description of the calyx which was given by Sars as the result of his study of the Norwegian specimens without interbasal sutures. In order to verify the truth of his analysis of the calyx, Pourtalès "forced a needle through the central hole of the calice of a *Rhizocrinus lofotensis* until it split. The fractures followed the joints between contiguous basals and between the latter and the first radials."

These important observations were entirely overlooked by Ludwig,[1] who followed Sars in describing the subradial part of the calyx as an enlarged uppermost stem-joint. He took, however, another and more correct view of the circular plate which Sars had called the basal rosette (Pl. VIIIa. figs. 6, 7; Pl. X. figs. 1, 4—*br*); for he regarded it as an unusual development of the calcareous network which occupies the central portion of the radial funnel in all Crinoids (compare Pl. XX. figs. 4, 6, 8) and surrounds the plexiform gland ascending from the chambered organ (Pl. XXIV. figs. 8, 9; Pl. LVIII. figs. 2, 3—*rp*).

I have long ago expressed my acceptance[2] of this modification of Sars's views which we owe to Ludwig; but I could never quite reconcile myself to believe in the account which he gives of the basals of *Rhizocrinus*. Having disestablished the rosette of Sars, he found it necessary to seek elsewhere for the missing basals of this type; and here he fell into error, probably, I think, from a too exclusive reliance on his interpretation of sections through the decalcified calyx, without properly considering the characters of an isolated calyx minus its muscles and ligaments, such as was excellently figured by Sars in his Tab. ii. fig. 43.

A horizontal section through the upper part of the calyx (Pl. VIIIa. fig. 7), or a view of the calyx from above (Pl. X. figs. 1, 4), like those given by Sars, shows five (or six) apparently interradial pieces (*mp*) surrounding the so-called basal rosette (*br*), and occupying the interval between it and the large muscular and ligament-fossæ on the sloping distal faces. Sars considered these pieces, and rightly so, as integral parts of the first radials. Ludwig's sections, however, led him to believe that these pieces (Pl. VIIIa. fig. 7, *mp*) "nicht radiär, wie es nach der Sars' schen Auffassung sein müsste, sondern interradiär liegen, so nämlich, dass stets die Mittellinie eines jeden Stückes B in die Trennungsebene zweier aneinanderstossender Radialien fällt."[3] The interradial position of the pieces in question is, however, shown just as well in Sars's figures as in those of Ludwig, who had no real grounds for stating that Sars had indicated their boundaries incorrectly. He considered that their interradial position precluded their being connected with the radials, and was therefore led to regard them as "nach innen verschobene und

[1] *Zeitschr. f. wiss. Zool.*, 1877, Bd. xxix. pp. 66–68.

[2] On some points in the Anatomy of Pentacrinus and Rhizocrinus, *Journ. Anat. and Physiol.*, 1877, vol. xii. p. 50.

[3] The apparently interradial position of these pieces (*mp*) is more marked in Ludwig's figures, where they are lettered B, owing to the semidiagrammatic character of these figures and the omission of the interarticular and dorsal ligaments.

in ihrer ursprünglichen Gestalt veränderte Basalia." He supposed these basals to be in a more embryonic condition than those forming the rosette of *Comatula*, and still remaining independent of one another as five isolated plates. But if this be the case one would surely expect to find the basals below the radials, and separating them from the top stem-joint as in the early stages of the Pentacrinoid larva of Comatulæ and in the Stalked Crinoids generally.

Ludwig, however, represents the supposed basals both in horizontal and in vertical sections as occupying a position *above* the radials, and forming the floor of the body-cavity some way above the chambered organ, with which the basals of Crinoids are always closely related. The position assigned by him to the basals of *Rhizocrinus* is one which I have no hesitation in describing as utterly impossible for these plates to occupy; and the dotted line inserted in his longitudinal section to mark the junction of the supposed basals with the first radials below them is purely imaginary. The same may be said of the lines that indicate an enveloping of the radials by upward processes of the supposed top stem-segment below them, which would cut off the radials altogether from the exterior of the calyx (compare wood-cut, fig. 17). That part of the calyx of *Rhizocrinus* which was considered by Ludwig to represent the embryonic basals altered in position, though not in nature, really belongs to the radials as was figured by Sars,[1] who spoke of these plates as follows:—"étant tronquées dans leur partie intérieure, elles forment réunies un large anneau en laissant entre elles au milieu un espace arrondi ou un peu pentagone, rempli par la plaque 'en rosette' (fig. 42, 43, *r*) mentionnée plus haut, reste probable des basales. Au point où cette plaque rencontre le bout tronqué

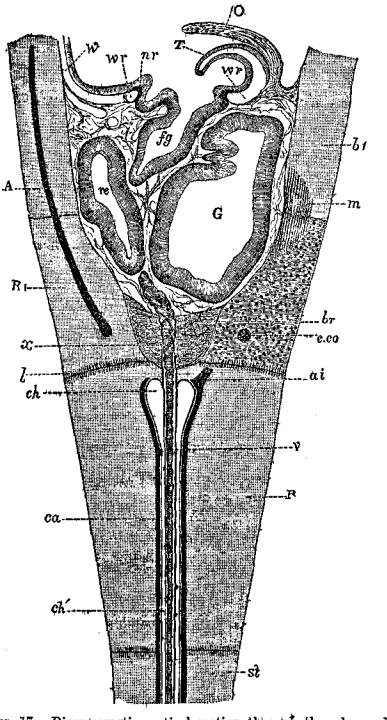


FIG. 17.—Diagrammatic vertical section through the calyx and disk of *Rhizocrinus lofotensis*; × 75. Altered from Ludwig. The section is represented as passing through the middle line of a ray on the left hand side, and as almost (but not quite) interradial on the right. *A*, axial cord of ray; *ai*, primary interradial cord; B, basal tube; b_1, first brachial; *br*, central calcareous plug, the basal rosette of Sars; *ca*, fibrillar sheath round vascular axis of stem; *ch*, chambers of the quinquelocular organ; *ch'* their downward extension into the stem; *c.co.*, portion of circular commissure formed by the secondary interradial cords; *fg*, fore-gut; *G*, mid-gut; *l*, basiradial ligament; *m*, muscle; *nr*, oral ring of the ambulacral nervous system; O, oral plate; R_1, radial; *re*, rectum; *st*, top stem-joint; T, tentacle; *v*, central vessel of stem; *w*, radial water-vessel; *wr*, water-vascular ring; *x*, plexiform gland.

[1] Crinoïdes vivants, p. 14.

intérieur ou aminci des radiales, on remarque à chacun d'elles un petit trou rond, d'où sort un sillon droit et linéaire (fig. 43, *s*), qui longe la ligne médiane de la face supérieure ou ventrale de chaque article et continue son parcours en remontant aussi de long du milieu de la face ventrale des radiales suivantes." This interior truncated portion of the radials is really their ventral face; while the openings at its central portion are the ends of the axial radial furrows descending to the lower part of the calyx, and the furrows proceeding outwards from them are the ventral radial furrows (Pl. VIIIa. fig. 7; Pl. X. figs. 1, 4—*vrf*) as described and figured by Sars, though Ludwig took them for interbasal sutures. Sars's fig. 42 is particularly instructive in this respect, as four out of the five first brachials are *in situ*, and their ventral furrows are seen to be continued downwards on to the radials.

The ventral interradial furrows which are so marked on the upper aspect of the calyx of many Comatulæ are absent or but slightly indicated in *Rhizocrinus*. Traces of them may be seen, however, in fig. 42 on Tab. ii. of Sars's memoir. But the adjacent muscle-plates of every two contiguous radials are intimately fused and also slightly everted. Each is separated from its fellow on the same radial by a well marked, ventral radial furrow; and the united halves of the inner faces of adjacent radials thus assume somewhat the appearance of isolated interradial plates resting within and against the outer faces of the radials. Ludwig was thus led to consider them as basals, and so to fall into exactly the same kind of error with regard to their genetic relations as he attributed to Sars.

I have nothing to add to his account of the chambered organ; but his description of the cords which proceed from its fibrillar envelope needs a little modification. He has pointed out that they are interradial and not radial as described by Sars; but he says that they "verbinden sich dann in den untersten Radialien durch Commissuren, ohne dass vorher eine Gabelung stattgefunden hätte." Were this really the case, *Rhizocrinus* would be a much more anomalous form than it actually is. For in all other Crinoids, recent or fossil, in which this point has been worked out, with the exception of *Bathycrinus*, the primary interradial cords fork within the basals, and there are two openings either on the inner (Comatulæ) or on the under face (*Pentacrinus*) of each first radial (Pl. XII. figs. 11, 22; Pl. XX. fig. 9). Ludwig, however, figures these cords [1] in *Rhizocrinus* as single so long as they remain within the basals (top stem-joint, Ludwig); and he believes them to fork in the suture between two radials, so that their branches would not enter the radials through their inner or under faces, but at their lower lateral angles.

This is not quite the case, however, and it is probably to be explained by Ludwig's having used the section-method only, without attempting to separate the pieces of the calyx. This operation is one of no little difficulty, and some of the radials are sure to be fractured in the process; but others separate from the basals along the sutural lines, and the arrangement of the canals can then be seen. The radials are comparatively low

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxix. p. 72, 1877, Taf. vi. fig. 18.

externally, and their upper and under faces approach one another rather sharply, owing to the convexity of the upper surface of the basals, so that their inner ends are very thin. The centre of the funnel which they form is occupied by the compact plug of close calcareous network which was mistaken by Sars for a basal rosette (Pl. VIIIa. fig. 7 ; Pl. X. figs. 1, 4—*br*). This is attached firmly to the inner ends of the radials, and comes away with them. It lies on the top of the convex upper surface of the basals, the sloping sides of which are divided into fossæ for the reception of the radials. Close to the inner end of each fossa is an elongated opening; and there is a similar one at the centre of the inner end of each radial; but it is not exposed until after the removal of the central plug. Ludwig's view, however, requires that there should be an opening at the inner lateral angle of each radial and none in the centre, as is really the case. The inference from this fact is that the primary interradial cords actually fork in the basals, and that the left branch of one fork, and the right branch of the next one pass out together through one of the elongated openings on the upper surface of the basal ring, which crosses the line of the interbasal suture. I find this to be actually the case. Sections through the uppermost part of the basal ring, above the level of the chambered organ, clearly show the forking of the primary cords, though no interradial lines of suture are visible at these points, as should be the case on Ludwig's theory of the composition of the calyx. At the same time I can readily understand how the use of the section-method alone led him to fall into this error. For owing to the convexity of the upper surface of the basals, a horizontal section through their central upper part might pass through the lowest and outer edge of the radial pentagon, and thus show interradial sutures, although the central portion of the section with the forking cords really belonged to the basals. The question is not a very important one ; and but for my having been able to examine a dissected calyx, the exclusive use of the section-method would have led me to follow Ludwig's description, except in one point. He does not seem to have noticed the presence of the intraradial commissures first described by himself in *Antedon ;* for he neither mentions them, nor introduces them in his diagram and figures. The special interradial commissures are of course absent, being unctionally replaced by the secondary interradial cords; but every two of these which converge within the substance of a radial are united by an intraradial commissure, just as they are in the Comatulæ. This is clearly distinguishable in both the series of horizontal sections which I have cut through the calyx of *Rhizocrinus lofotensis* (Pl. VIIIa. fig. 6, *ico*).

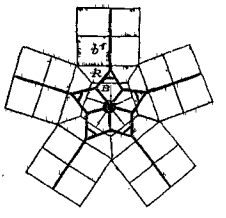


FIG. 18.—Diagram of the distribution of the axial cords in the calyx of *Rhizocrinus lofotensis*. B, basals; R, radials; b^1, first brachials.

The distribution of the axial cords in the calyx of *Rhizocrinus* is thus somewhat different from that described by Ludwig, as will be seen if the accompanying woodcut (fig. 18) be compared with fig. 18 on Taf. vi. of his memoir.

There is another point in the anatomy of *Rhizocrinus* which is not brought out at all in the semidiagrammatic figure given by Ludwig (Taf. v. fig. 7). The second brachials (third radials of his nomenclature) are relatively much too small; but whether he purposely neglected the appearance presented by them, or whether they were really small and undeveloped in his specimens from reparation after injury, I cannot say. The whole of the visceral mass is occupied by the winding gut (Pl. VIIIa. fig. 8, G); so that the body-cavity is reduced to a minimum. But the outline of the visceral mass is not circular as represented by Ludwig, for a large diverticulum of the gut extends outwards between every two brachials. These approach one another over its outer end, so as to protect it, and it is supported on either side by one of the large processes bordering the ventral furrows of the brachials which were described and figured by Sars. This is well shown in the left hand portion of Pl. VIIIa. fig. 8; while the right hand side shows the second brachials almost meeting one another over the interradial diverticulum of the rectum. The visceral mass and third radials of *Bathycrinus* present the same characters as seen in Pl. VII. fig. 4*a*, and Pl. VIIb. fig. 7, the first of which shows the great processes on the ventral face of the axillary radial. It would be interesting to determine whether the axillaries of *Bourgueticrinus* present similar processes.

The syzygies of *Rhizocrinus*, at any rate in the lower parts of the arms, are slightly different in character from those of other Crinoids. The apposed faces are not completely striated as in *Comatula*, or even partially so as in *Pentacrinus* (Pl. XII. figs. 7, 10, 18, 21; Pl. XXI. figs. 1 *d*, 2 *d*, 5 *a*; Pl. XXX. figs. 20, 21), as Sars has already pointed out in the case of *Rhizocrinus lofotensis*.[1] Neither, however, are they perfectly simple, as is sometimes the case in *Pentacrinus* (Pl. XXVI. figs. 5, 8; Pl. XXXVII. figs. 3, 4; Pl. L. figs. 6, 7, 12, 13). For there is an indistinct vertical ridge around the opening of the central canal of the hypozygal, resembling that of a bifascial articulation; and this forks at its lower end so as to enclose a somewhat triangular pit into which there fits a corresponding process of the epizygal. The hypozygal faces which I have found to show this character most clearly are those of the first brachials of a *Rhizocrinus rawsoni* from the Azores (Pl. X. fig. 8). It is less visible in the corresponding joints of the Havana specimen (Pl. X. fig. 6). It likewise appears, though less distinctly, on the first brachials of a specimen of *Rhizocrinus lofotensis* from Havana (Pl. X. fig. 1). Sars makes no reference to it in his description of this species, but the pit on the distal face of the first brachial is clearly shown in his Tab. iii. fig. 53, and also in a dorsal view (fig. 54). The backward projection on the second brachial of *Rhizocrinus rawsoni* is represented in Pl. X. fig. 19; while figs. 17 and 18 show the apposed faces of a syzygial union farther out on the arms, the backward process of the epizygal and the corresponding pit on the hypozygal being very distinct.

A curious peculiarity which is presented by one of the Azores specimens of *Rhizocrinus*

[1] Crinoïdes vivants, pp. 15, 22.

rawsoni is shown in Pl. X. fig. 8. The adjacent edges of two contiguous first brachials send out short processes which meet one another and rest upon the fused muscle-plates of the two radials beneath, so as to cut off a tubular space from the body-cavity. I have found nothing like this in either of the other specimens, which have lost all the visceral mass together with the second and following brachials (Pl. X. fig. 6). The structure in question may be only accidental, or on the other hand it may perhaps have some relation to the anal tube.

The presence of the syzygy between the first and second brachials of *Rhizocrinus* renders it a matter of some difficulty to obtain entire specimens, especially of *Rhizocrinus rawsoni*. For the arms break away at this point, carrying with them the entire visceral mass. This is the condition of the individuals represented in Pl. X. figs. 1, 6, 8; while fig. 20 shows the arm-bases from the second brachial onwards, and the visceral mass which they enclose. Two of them have been removed so as to expose the simple digestive apparatus, with the oral plates around the mouth and a relatively long anal tube. The position of the genital glands in the pinnules borne by the epizygals of the third syzygial pair is also well shown.

I am strongly inclined to believe that the loss of the visceral mass and arm-bases may occur and be made good during life. This appears to have taken place in the Havana specimen represented in Pl. X. fig. 7. Small oral plates are visible in the centre at a point much below their usual level, which is seen in fig. 20; while the second brachials are so much smaller than the first that the difference is evidently due to fracture and reparation, just as so often occurs on the arms of *Pentacrinus* and *Comatula*. But in this case all the arms broke away together, carrying the visceral mass with them, so that a new one had to be developed within the ring of regenerated arms. Not much is to be seen of it, however, except the oral plates, the replacement of which is a point of considerable interest. It has long been suspected that eviscerated Comatulæ have the power of restoring their disks;[1] but this is the first instance of the kind that I have met with in a Stalked Crinoid.

Owing to the fact that the ring of anchylosed basals in *Rhizocrinus* was at first regarded as an enlarged top stem-joint, the affinity between this genus and *Bourgueticrinus* has been supposed to be much closer than can be admitted in the light of our present knowledge. For in some respects *Rhizocrinus* stands farther from *Bourgueticrinus* than even *Bathycrinus* does. The fossil genus *Mesocrinus*,[2] although still but imperfectly known, is probably nearer *Bourgueticrinus* than either of these two genera. But it appears to differ from them in the smaller size of the upper stem-joints, a point in which it resembles both *Rhizocrinus* and *Bathycrinus*. In the two best known species

[1] See Marshall, *Quart. Journ. Micr. Sci.*, 1884, vol. xxiv., N. S., pp. 525, 526.

[2] On Two New Crinoids from the Upper Chalk of Southern Sweden, *Quart. Journ. Geol. Soc.*, vol. xxxvii. p. 130, pl. vi. figs. 1–7.

of *Bourgueticrinus* (*ellipticus* and *æqualis*) the uppermost part of the stem is formed of joints of an altogether different character from those which are to be found lower down. The latter are wider than high, with articular faces of a pointed oval shape, the two diameters of the oval being very unequal in length. Towards the upper part of the stem this inequality disappears, and the joints become more discoidal, though never thin and lamellar, as in the highest part of the stem of *Rhizocrinus* and *Bathycrinus* (Pl. VII. figs. 2, 11; Pl. VIIIa. fig. 1; Pl. IX. figs. 1–3; Pl. X. fig. 2). Above these discoidal joints, however, the stem gradually enlarges, and from two to four of the uppermost joints on which the calyx rests are of great relative size, both height and diameter being considerable. Sometimes the top joint is highest and sometimes the one below it; but at any rate one or more of these large upper joints remain united with the calyx to form the so-called summit. The upper stem-joints of *Apiocrinus* are not as a rule much higher than those below them; but the diameter often increases considerably from a point in the stem a little way below the calyx, so that a tolerably large number of joints enters into the composition of the summit. In species like *Apiocrinus crassus*, *Apiocrinus magnificus*, and *Apiocrinus murchisonianus*, however, there is scarcely any enlargement of the stem below the calyx, the uppermost joints, except the highest one on which the basals rest, being but little if at all larger than those below them. The same variations appear in *Millericrinus*. *Millericrinus nodotianus* has high upper joints, while those of *Millericrinus simplex* are thin and discoidal externally; though the uppermost joint has a large synosteal surface for the reception of the basals which rest upon it.

It seems to me very probable, therefore, that the existence of similar variations will have to be admitted in *Bourgueticrinus;* though on the other hand a revision of the genus may result in the transfer of all the species without enlarged upper stem-joints to *Rhizocrinus* or *Mesocrinus*, especially if the articular faces of their radials are well developed and not reduced to a minimum as in *Bourgueticrinus æqualis*. But I am quite prepared to have to abandon *Mesocrinus* as a distinct generic type, and to modify the descriptions of *Bourgueticrinus* which are given by palæontologists so as to include in this genus the two species *Mesocrinus fisheri* and *Mesocrinus suedicus*, on which the genus *Mesocrinus* was based.

Even then, however, *Apiocrinus* and *Bourgueticrinus* would differ from *Rhizocrinus* and *Bathycrinus* in the character of the upper stem-joint. In the two genera last mentioned, as in *Pentacrinus*, this joint is the youngest and smallest of the whole stem, being merely a delicate film of calcareous reticulation which is received into and concealed by the curved under surface of the basals. In *Apiocrinus*, however, and in *Bourgueticrinus* this upper joint, though perhaps small externally, is large internally and supports the basals in five large fossæ on its surface.

As it closes the calyx below and really belongs thereto, de Loriol[1] has called it the

[1] Swiss Crinoids, p. 6; Paléont. Franç., *loc. cit.*, p. 19.

"article basal." It is entirely undeveloped in *Rhizocrinus*, though this type shows a slight decrease in the width of the stem a little below the cup, before the commencement of the gradual downward enlargement, just as is so much more marked in *Bourgueticrinus*.

There are certain other points in which the two recent species of *Rhizocrinus*, together with some fossil ones, differ very markedly from *Bourgueticrinus;* and although these differences hold good for some of the fossil species of *Rhizocrinus*, it is difficult to say how far this may be the case with others, owing to their imperfect state of preservation.

In the first place, the basals are of great relative height, often five or six times that of the radials, and they occupy much the larger part of the exterior of the calyx; while the lower stem-joints are usually longer than wide. If they bear radicular cirri these come off somewhat irregularly from near the ends of the joints, but their sockets are not verticillate, nor are they ever formed by portions of two apposed joints, as is often the case in *Bourgueticrinus* and *Mesocrinus*. *Rhizocrinus lofotensis* and *Rhizocrinus rawsoni* show these characters very well (Pl. IX. fig. 1; Pl. X. fig. 15). The latter has the longer basals, but its stem-joints, though longer than wide, are not so markedly so as in *Rhizocrinus lofotensis*. The same is the case with the stem-joints of the so-called *Bourgueticrinus londinensis*, which is really a well-defined *Rhizocrinus;* while in those of *Conocrinus* (*Rhizocrinus*) *suessi* and *Conocrinus pyriformis* the width of the articular faces is more nearly equal to the length of the joint. In all these species the basals are longer than the radials, though not greatly so; but in *Bourgueticrinus* (*Rhizocrinus*) *thorenti* they are very long, as in the recent *Rhizocrinus rawsoni*, while the stem-joints resemble those of *Rhizocrinus lofotensis* in their proportions.

Owing to the shape of the basals, the calyx of *Rhizocrinus* is usually cylindrical or obconical, and though it expands gradually upwards it is nowhere very greatly wider than the stem, as is the case in *Bourgueticrinus*. In *Conocrinus suessi* and in *Conocrinus pyriformis*, and perhaps also in *Conocrinus seguenzai*, it takes on a more ovoid form; while in *Rhizocrinus rawsoni* and *Rhizocrinus thorenti* it may be very considerably elongated.

So far as I am aware, no true *Rhizocrinus* has been obtained from any formation lower than the Eocene. Quenstedt[1] figures some moderately elongated stem-joints of *Apiocrinus constrictus* from the White Chalk of Rügen. But in the absence of a calyx it is almost impossible to determine these generically, owing to the rarity of the association of calyces and stem-joints at the same spot. The same is the case with regard to the Jurassic species of *Bourgueticrinus, e.g., Bourgueticrinus ooliticus* from the Bradford Clay, which is perhaps referable to *Thiollericrinus* as suggested by de Loriol. The distinguished Swiss palæontologist has also described a fossil from the Cretaceous of Alabama, U.S., as *Bourgueticrinus alabamensis*.[2] It consists only of the basal cone which "supports the calyx, and which is composed of several enlarging segments of the

[1] Encriniden, Tab. 104, figs. 64–66.

[2] Description of a New Species of Bourgueticrinus, *Journ. Cincinn. Soc. Nat. Hist.*, vol. v. p. 118, pl. v. fig. 1.

column surmounted by the basal plates." His figure shows five of these uppermost stem-joints, which are all low and discoidal; and it consequently appears to me that the fossil should be referred to *Rhizocrinus* rather than to *Bourgueticrinus*. If this be the case, and its horizon really Cretaceous, this species is of interest as being the only known instance of a Cretaceous *Rhizocrinus*.

On the other hand, *Bourgueticrinus* although abundant in Cretaceous deposits, is not certainly known to occur in any Tertiary formation. Some of the types described under this generic name from the Italian Tertiaries have been referred to *Conocrinus* by Meneghini and others. Among these is the *Apiocrinus cornutus* of Schafhäutl, which was doubtfully referred to *Bourgueticrinus* by Meneghini;[1] though Zittel,[2] while describing its calyx as "niedrig schüsselförmig," spoke of it as *Conocrinus cornutus*. I have been enabled by the kindness of Prof. Zittel to examine the calyx of this species for myself; and I was interested in finding its shape to be very like that of a singular bowl-shaped calyx from the London Clay which is preserved in the Natural History Museum. This has relatively large radials and low basals. I do not see how it can possibly be placed in the same genus as *Conocrinus thorenti* or *Rhizocrinus rawsoni* with their elongated calyces mainly formed by the long basals; and I think that it will be necessary to establish a new genus for the reception of these two species, to which others will probably be added when the calyces are found corresponding to some of the other Tertiary stem-joints that are now referred to *Bourgueticrinus* in default of further evidence, *e.g.*, *Bourgueticrinus didymus*, Schaur.

Rhizocrinus was supposed by Pourtalès to have a considerable resemblance to the genus *Belemnocrinus* from the Burlington limestone of Iowa and Illinois. Wachsmuth and Springer[3] have spoken of this resemblance as being very close and interesting, and stated that "the most important difference, and indeed the only essential distinction between these genera in their external structure, is found in the solid proboscis and covered dome of *Belemnocrinus*." It appears to me, however, that the American authors lay too much stress on the fact that the calyx is formed in both genera of five long and narrow basals, and that they have overlooked other and more important structural characters. In the first place the stems of the two types are totally different. That of *Belemnocrinus* is pentagonal, consisting of short joints with crenulated faces; while the stem-joints of *Rhizocrinus* are elongated and more or less dice-box shaped, with the well known, enlarged and elliptical ends. Stem-joints articulated like those of *Rhizocrinus* do indeed occur in the Palæozoic *Platycrinus*, and under these circumstances we may fairly expect that any genetic relationship between *Belemnocrinus* and *Rhizocrinus* would have manifested itself in this character. But the stem of *Belemnocrinus*, at any rate of *Belemnocrinus florifer*, seems to have borne successive

[1] *Atti della Soc. Tosc. di Sci. Nat.*, vol. ii. p. 53.

[2] Palæontologie, Bd. i. p. 392.

[3] Revision of the genus Belemnocrinus, and description of two new Species, *Amer. Journ. Sci. and Arts*, 1877, vol. cxiii. p. 255.

verticils of five cirri, just like that of a recent *Pentacrinus;* and this is a much more important morphological resemblance than the length of the basal plates.

Then again the radials of *Rhizocrinus* are all in close lateral contact, while *Belemnocrinus* has an anal plate intervening between two of the radials and resting on a basal. It supports a heavy proboscis on its upper face, while *Rhizocrinus* has a disk protected by five insignificant oral plates. The arms of *Belemnocrinus* are ten in number, while *Rhizocrinus* has only five. This, however, is unimportant; but the arms of *Belemnocrinus* bear two rows of pinnules alternately, while in some species these primary pinnules bear alternating secondary ones, a condition totally unknown in any Neocrinoid. Altogether, therefore, the structure of the arms of *Belemnocrinus* is very different from that of *Rhizocrinus*, in which every joint has a syzygial surface at one of its ends; though it must be admitted that syzygies are plentiful in the arms of *Belemnocrinus*, as there are some species, *e.g.*, *Belemnocrinus pourtalesi*, in which "throughout the greater portion of the arms every alternate joint is a syzygium." This character, however, and the length of the basals are of minor importance compared to the intercalation of the anal plate in the calyx and the nature of the articulation between the stem-joints, so that I cannot in any way regard *Belemnocrinus* as an ancestral form of *Rhizocrinus*.

1. *Rhizocrinus lofotensis*, M. Sars, 1864 (Pl. VIIIa. figs. 6–8; Pl. IX. figs. 1, 2; Pl. X. figs. 1, 2).

1864. *Rhizocrinus lofotensis*, M. Sars, Forhandl. Vidensk. Selsk., p. 127.
1868. *Rhizocrinus lofotensis*, M. Sars, Mémoires pour servir à la connaissance des Crinoïdes vivants, p. 38.
1868. *Bourgueticrinus Hotessieri*, Pourtalès, Bull. Mus. Comp. Zoöl., vol. i., No. 7, p. 128.
1872. *Rhizocrinus lofotensis*, Wyv. Thoms. (pars), Proc. Roy. Soc. Edin., vol. vii. p. 770; The Depths of the Sea, 1873, pp. 447, 450.
1874. *Rhizocrinus lofotensis*, Pourtalès, Ill. Cat. Mus. Comp. Zoöl., vol. iv., No. 8, p. 28.
1882. *Rhizocrinus lofotensis*, P. H. Carpenter, Bull. Mus. Comp. Zoöl., vol. x., No. 4, p. 173.
1884. *Rhizocrinus lofotensis*, P. H. Carpenter, Proc. Roy. Soc. Edin., vol. xii. p. 356.

Dimensions.

Greatest length of stem (Pourtalès),	5 inches.
Greatest length of stem (Sars), sixty-seven joints (?)	70 mm.
Greatest length of entire specimen (Sars),	80 „
Greatest length of arm, about thirty-five joints (Sars),	11 „

Stem slender, bearing branching radicular cirri on its lower part, and ending below in a more or less spreading root. The cirri come off near the terminal faces of the lower joints at the ends of their longer axes. The joints are markedly dicebox-shaped, and nearly three times as long as wide.

The calyx is smooth and obconical, of somewhat variable proportions. Basals two or

three times the height of the radials, and closely fused, so that their sutures are rarely visible. Radials short and quadrate, with concave upper and convex lower edges; usually five in number, but sometimes four, six, or seven. Arms of from thirty to forty joints, which are united in pairs by syzygies. First brachials flattened, and quite free laterally, square or slightly longer than broad. The second similar, but somewhat shorter. The third still shorter and trapezoidal, so that the arm narrows considerably at this point. The remaining joints as long or a little longer than wide, and more convex than the preceding ones. The epizygals which bear the pinnules are rather longer than the hypozygals and irregularly pentagonal, as the pinnule facets are large relatively to the length of the joints. The first pinnule is on the eighth brachial or fourth epizygal. The two lowest pinnule-joints are somewhat trapezoidal in shape, and in contact by their broader ends. The remaining joints have a medio-dorsal keel and flattened sides, with the edge of the ventral furrow produced upwards into broad thin plates, especially in the third and following joints. The peristome is at the level of the second brachial, and protected by five linguiform oral plates which occupy the central ends of the interpalmar areas.

Colour, in spirit, brownish-white or greyish-white.

Localities.—The Lofoten Islands, 80 to 300 fathoms; the Josephine Bank.

H.M.S "Lightning," 1868. Station 12. Lat. 59° 36′ N., long. 7° 20′ W.; 530 fathoms; Globigerina ooze; bottom temperature, 47°·3 F. Three small specimens without arms.

Station 16. Lat. 61° 2′ N., long. 12° 4′ W.; 650 fathoms; Globigerina ooze. Two small specimens without arms.

Stem-fragments were occasionally found in the "cold area" during the cruises of the "Lightning" and "Porcupine."

H.M.S. Challenger. Station 24A. March 25, 1873, off Culebra Island; lat. 18° 43′ N., long. 65° 5′ W.; 625 fathoms; Pteropod ooze. Two specimens.

Station 122C. September 10, 1873, off Barra Grande; lat. 9° 10′ S., long. 34° 49′ W.; 400 fathoms; red mud. Two specimens.

Station 323. February 28, 1876; lat. 35° 39′ S., long. 50° 47′ W.; 1900 fathoms; blue mud; bottom temperature 33°·1 F. The occurrence of a stem-fragment here is recorded in the Station-book, but it has not come into my hands, and I am therefore unable to speak positively about it.

H.M.S. "Knight Errant," 1880. Station 5. Lat. 59° 26′ N., long. 7° 19′ W.; 515 fathoms; mud; bottom temperature, 45°·4 F. Two young specimens without arms.

Station 6. Lat. 59° 37′ N., long. 7° 19′ W.; 530 fathoms; grey mud; bottom temperature, 46°·5 F. A fragment only.

Rhizocrinus lofotensis has also been dredged several times by the surveying ships of the U. S. Coast Survey, as recorded in the following list.

SS. "Bibb," May 4, 1868, off the Samboes; 237 fathoms. May 11, 1868, off Sand Key; 248 and 306 fathoms. March 4, 1869, off Cojima, near Havana; 450 fathoms; and several times at lesser depths.

SS. "Blake," 1877–78. No. 29, lat. 24° 36′ N., long. 84° 5′ W.; 955 fathoms; bottom temperature, 39½°. No. 35, lat. 23° 5′ 46″ N., long. 88° 58′ W.; 804 fathoms; bottom temperature, 40½°. No. 43, lat. 24° 8′ N., long. 82° 51′ W.; 339 fathoms; bottom temperature, 40°. No. 44, lat. 25° 33′ N., long. 84° 35′ W.; 539 fathoms; bottom temperature, 39½°. No. 56, off Havana, lat. 22° 9′ N., long. 82° 21′ 30″ W.; 175 fathoms.

1878–79. No. 238, off Grenadines, 127 fathoms; fine coral sand; bottom temperature, 56°. No. 248, off Grenada; 161 fathoms; fine grey ooze; temperature, 53½°. No. 259, off Grenada; 159 fathoms; bottom temperature, 53½°. No. 274, off Barbados; 209 fathoms; fine sand and ooze; bottom temperature, 53½°.

1880. No. 306, lat. 41° 32′ 50″ N., long. 65° 55′ W.; 524 fathoms.

U. S. Fish Commission, 1882. No. 1124, S.S.E. off Nantucket; 640 fathoms.

Remarks.—An elaborate account of this well-known species has already been given by Sars, and I have little to say about it except on one or two points. (1) The subradial portion of the summit is not formed by the top stem-joint as supposed by him, but it consists of anchylosed basals, as was originally described by Pourtalès.[1] (2) I have also followed Pourtalès in considering the two joints immediately above the radials as the two lowest brachials, and not as the second and third (axillary) radials, as they have been called by Sars, Ludwig, and Wyville Thomson. No matter what the number of arms of a Crinoid, the so-called second and third radials are morphologically brachials, as I have already pointed out (*ante*, pp. 47, 48); and though it is convenient for descriptive purposes to speak of the successive divisions of the rays as radials, distichals, and palmars, I see no advantage whatever in calling the two lowest arm-joints of a five-armed Crinoid the second and axillary radials. That they are homologous with the second and third radials of *Comatula* and *Pentacrinus* is undisputed, but these are fundamentally brachials; and as it is the distinctive character of an axillary joint that it should bear two arms (or arm-divisions) on its distal face, the use of the term "axillary" in the case of a five-armed Crinoid is misleading and unnecessary.

There is another point in Sars's description that I would just notice. On p. 23 he says distinctly that the covering plates of the ambulacra occur "sur le disque, aussi bien que dans toute la longueur des bras et des pinnules." But there is no sign of them in either of his figures of the disk (Tab. iv. figs. 85, 86, 89). In fact, in fig. 85 no covering plates are represented at all, though the food-groove is shown as far as the distal part of the second brachial; while in the other two figures the first covering plate is shown resting on the distal part of the second, or the lower part of the third brachial.

The form of the calyx in this species varies very considerably; for it is nearly hemispherical in some specimens and much elongated in others. These last have the best developed arms; and to some extent, therefore, the forms with a low and wide cup must be regarded as premature. But differences of development will not entirely account for the variation, as the calyx of a young specimen found by Sars[1] is distinctly higher (longer) than broad.

[1] Crinoïdes vivants, Tab. iv. fig. 95.

2. *Rhizocrinus rawsoni*, Pourtalès, 1874 (Pl. IX. figs. 3–5; Pl. X. figs. 3–20; Pl. LIII. figs. 7, 8; woodcut, fig. 19).

1872. *Rhizocrinus lofotensis*, Wyv. Thoms. (pars), Proc. Roy. Soc. Edin., vol. vii. p. 770; The Depths of the Sea, 1873, p. 450.
1874. *Rhizocrinus Rawsonii*, Pourtalès, Ill. Cat. Mus. Comp. Zoöl., vol. iv., No. 8, p. 27.
1882. *Rhizocrinus rawsoni*, P. H. Carpenter, Bull. Mus. Comp. Zoöl., vol. x., No. 4, p. 173.
1883. *Democrinus Parfaiti*, Perrier, Comptes rendus, t. xcvi., No. 7, p. 450.
1883. *Rhizocrinus rawsoni*, P. H. Carpenter, Ann. and Mag. Nat. Hist., ser. 5, vol. xi. p. 335.
1884. *Rhizocrinus rawsoni*, P. H. Carpenter, Proc. Roy. Soc. Edin., vol. xii. p. 357.

Dimensions.[1]

Greatest length of entire specimen (Captain Cole),	190·0 mm.
Greatest length of stem, sixty-eight joints ("Blake" specimen),	180·0 „
Greatest length of calyx ("Blake"),	6·0 „
Greatest diameter of same calyx,	2·5 „
Greatest length of arm, sixty double joints (Captain Cole),	75·0 „

Stem robust, bearing few radicular cirri on its lower part, but ending below in a long spreading root which attaches itself at intervals. The joints are from once and a half to twice (*rare*) as long as broad, and tolerably cylindrical or barrel-shaped in outline. The planes of the articular ridges at their ends cross one another, but the ends are not much expanded, so that the dice-box shape is but little marked. The calyx is very variable in form, sometimes long and slender, sometimes short and broad. The expansion from below upwards is rarely quite uniform, and there is often a more or less defined constriction about the level of the basiradial suture. The basals are separated by distinct sutures, and are generally four or more times the height of the radials, which are five in number, and more or less distinctly pentagonal.

The arms may have one hundred and twenty joints united in pairs by syzygy. The first brachials are flattened, quite free laterally, and wider than long. The second are more nearly square, and the next four shorter but of about the same width, the last one (or the epizygal of the third syzygial pair) often bearing the first pinnule. The following hypozygal joints are obliquely oblong; while the epizygals are more irregular in shape, and sometimes almost triangular, so as to look like axillaries. The first pinnule is generally on the sixth or eighth brachial, but sometimes not till the fourteenth. The two lowest joints of the basal pinnules are broader than their successors, which are elongated and of gradually diminishing width.

The peristome is about at the level of the sixth brachial, and is protected by small oral plates.

Colour, in spirit, brownish-white or greyish-white.

Localities.—H.M.S. "Porcupine," 1869. Station 42. Off Cape Clear, lat. 49° 12′ N.,

[1] Some other measurements of particular details will be found on p. 265, where also reference is made to the unusually elongated calyx of the individuals dredged by the "Travailleur."

long. 12° 52′ W.; 862 fathoms; bottom temperature, 39°·7 F.; ooze with sand and shells. Two armless specimens.

Station 43. Lat. 50° 1′ N., long. 12° 26′ W.; 1207 fathoms; bottom temperature, 37°·7 F.; Globigerina ooze. Two young specimens, one without arms.

H.M.S. Challenger. Station 76. July 3, 1873; south of Terceira (Azores), lat. 38° 11′ N., long. 27° 9′ W.; 900 fathoms; Pteropod ooze; bottom temperature, 40° F. Three specimens without arms.

Rhizocrinus rawsoni has also been dredged by the surveying ships of the U. S. Coast Survey, as recorded in the following list.

SS. "Hassler," December 29–30, 1871. Off Sandy Bay, Barbados; 100 fathoms.

SS. "Blake," 1877–78. No. 32, off Havana; lat. 23° 32′ N., long. 88° 5′ W.; 95 to 175 fathoms.

1878–79. No. 155, off Montserrat; 88 fathoms; bottom temperature, 69° F. No. 166, off Guadeloupe; 150 fathoms; bottom temperature, 59½°. No. 177, off Dominica; 118 fathoms; bottom temperature, 65° fine sand and broken shells. No. 211, off Martinique; 357 fathoms; fine yellow sand and broken shells. No. 273, off Barbados; 103 fathoms; bottom temperature, 59½°; coral and broken shells, yellow. No. 277, off Barbados; 106 fathoms; bottom temperature, 58°; hard rocky bottom. No. 290, off Barbados; 73 fathoms; bottom temperature, 70¼°; coarse coral sand and broken shells. No. 296, off Barbados; 84 fathoms; bottom temperature, 61½°; hard bottom. No. 297, off Barbados; 123 fathoms; bottom temperature, 56½°; calcareous stones.

Telegraph steamer "Investigator," Captain E. Cole. Saba Bank; 200 fathoms. Fifteen miles N. by E. from Panama; 300 fathoms.

The French steamer "Travailleur," 1882,[1] "1900m. de profondeur sur les côtes du Maroc, par le travers du cap Blanc."

Also the "Talisman," 1883,[2] "Par le travers du cap Ghir et du cap Noun, à 120 milles environ de la côte," 2000 to 2300 metres.

Remarks.—The first examples of this type which were actually obtained were those dredged by the "Porcupine" in 1869, at depths of 862 and 1207 fathoms off Cape Clear (Stations 42 and 43). They were, however, considered by Sir Wyville Thomson merely as unusually large specimens of *Rhizocrinus lofotensis;* and the correctness of this identification would perhaps not have been doubted, but for the discovery in 1871 by the U. S. Coast Survey steamer "Hassler" of some fine individuals, which Mr. Pourtalès recognised as specifically distinct from *Rhizocrinus lofotensis.* Two specimens which were obtained by the Challenger in 900 fathoms among the Azores (Station 76) were at first referred to *Rhizocrinus lofotensis;* but having compared them with the *Rhizocrinus rawsoni* of the Caribbean Sea, I find that they likewise belong to that species. It is generally larger and more robust than *Rhizocrinus lofotensis*, and the calyx, instead of being regularly obconical, is extremely variable in form, as will be seen subsequently.

All the specimens that I have seen have been regularly pentamerous, while in *Rhizocrinus lofotensis* the number of radials is not unfrequently four or six (Pl. VIIIa. fig. 7), and may reach seven. Those of *Rhizocrinus rawsoni* are generally shorter

[1] *Comptes rendus*, t. xcvi. p. 459. [2] *Ibid.*, t. xcvii. p. 1392.

relatively to their width, than in *Rhizocrinus lofotensis*, while the third brachial is oblong and not trapezoidal, so that there is no sudden narrowing of the arm at the syzygy between the third and fourth brachials. The shape of the arm-joints too, especially of those which bear pinnules, is not the same in the two species; while the pinnules themselves, and more particularly those on the proximal parts of the arms, differ very considerably in appearance, those of *Rhizocrinus rawsoni* having broad lower joints.

The visceral mass of *Rhizocrinus lofotensis* is relatively lower than that of *Rhizocrinus rawsoni*, in which it is supported by the first six brachials (Pl. X. fig. 20); while in *Rhizocrinus lofotensis* the ambulacra leave the peristome at the level of the second brachials, on to which they pass.

The stem-joints of *Rhizocrinus rawsoni* are relatively shorter and thicker than those of *Rhizocrinus lofotensis*, in which the length is three times the width, and the radicular cirri at the base of the stem are much more numerous in this species than in *Rhizocrinus rawsoni*. In fact there are no radicular cirri whatever in one of the Challenger specimens of *Rhizocrinus rawsoni*, and only two, borne upon the first joint above the root, in one of those dredged by the "Porcupine." In correspondence with this, the root of *Rhizocrinus rawsoni* is more like that of *Bathycrinus*, the lowest stem-joint giving rise to three or more stout branches, which themselves eventually subdivide and bear radicular cirri (Pl. X. fig. 15). This condition appears to be comparatively rare in *Rhizocrinus lofotensis*, in which the lowest stem-joint is often provided with from five to nine slender cirri, but does not give attachment to a spreading root.

The longest cup yet known in *Rhizocrinus rawsoni* was found in some individuals which were dredged by the "Travailleur" in 1882, at a depth of 1900 metres (1000 fathoms), off Cape Blanc, on the coast of Morocco, and were referred by Prof. Perrier to a new genus *Democrinus*.[1] The cup is singularly elongated in form, as will be seen by comparing the measurements kindly furnished me by Prof. Perrier, with those given below for the Challenger, "Blake," and "Porcupine" specimens.

Democrinus Parfaiti, Perrier = *Rhizocrinus rawsoni*, Pourtalès.

Dimensions.

Length of the calyx from the terminal furrow to the first stem-joint,	9·0 mm.
Maximum diameter of the calyx,	2·0 „
Height of the radials,	0·2 „
Diameter of the stem-joints,	1·0 „
Length of the stem-joints,	2·0 „

The basals of this type thus form a cup 9 mm. high from its lower extremity to the constriction at the level of the basiradial suture; while its maximum diameter is not more than 2 mm., twice that of the stem-joints.

[1] *Comptes rendus*, t. xcvi., 1883, p. 450.

The following table shows the great amount of variation in the proportions of the basal tube in other individuals of *Rhizocrinus rawsoni*, together with its diameter as compared with that of the stem-joints.

Species.	How obtained.	Depth.	Basal tube.		Length of Stem.	Stem-joints.		
			Height.	Width.		Number.	Length.	Width.
		fathoms.			mm.			
Rhizocrinus rawsoni.	"Blake"	175	5·5	2·50	180	68	3·50	2·25
	Challenger.	900	5·0	2·00	150	53	3·00	2·00
	Capt. Cole, "Investigator."	300	3·5	3·00	145	45	3·50	2·25
	"Porcupine."	862	3·0	1·75	50	30	2·25	1·25
Rhizocrinus lofotensis.	Sars.	300	2·0	1·50	70	67	1·50	0·50

N.B.—Pourtalès described his largest specimen of *Rhizocrinus lofotensis* as having a stem nearly 130 mm. long and composed of fifty-nine joints, the length of which averages three times their diameter.

It will be seen from the above table that in absolute size, as well as in the proportions of the basals and of the stem-joints, the "Porcupine" examples of this type are those which approach *Rhizocrinus lofotensis* most nearly; though the stem is slightly more robust than in Perrier's specimens which have such an extraordinarily elongated calyx. Both are smaller than those from the Azores, which are themselves smaller than the Caribbean specimens (though not always so in the length of the cup), a fact which is doubtless due to variations of temperature. The difference in size between the largest individuals of *Rhizocrinus lofotensis* found by Sars and Pourtalès respectively is likewise probably the result of the difference between the temperature of the Gulf Stream in the Florida Straits and that of the north-east Atlantic.

The youngest specimens of *Rhizocrinus rawsoni* which I have seen are those dredged by the "Porcupine" in 1869 at a depth of 1207 fathoms off Cape Clear (Pl. LIII. figs. 7, 8). Each has twenty-eight joints in the stem from the calyx to the root; but its length, which is only 20 mm. in the smaller, is 24·5 mm. in the larger individual. The uppermost joints are decidedly wider than those below them, the majority of which are elongated and cylindrical, only a few at the base of the stem (more in the larger than in the smaller individual) having the characteristic dicebox shape, with expanded ends (Pl. LIII. fig. 7). The length of the calyx is almost the same in both specimens, 1·8 mm., though its diameter across the radials is greater in that which has the longer stem. It is mainly formed by the basals, which are 1·2 mm. in height. In the smaller individual (Pl. LIII. fig. 7) they expand very slowly upwards to the level of the lowest

angle of the basiradial suture, where a radial rests on two basals; and then the surface of the radials slopes outwards rather more rapidly than that of the basal tube below it, so as to considerably increase the diameter of the cup. All the sutures, interradial, basiradial, and interbasal, are perfectly distinct; and there is a very faint circular constriction of the basal tube rather below its middle, analogous to that described by Sars in certain individuals of *Rhizocrinus lofotensis*.[1] This smaller individual has the lowest portions of the arms preserved, the longest of which has small pinnule-stumps on the fourteenth and sixteenth brachials, *i.e.*, on the epizygals of the seventh and eighth syzygial pairs. In the larger individual, however, all the arms are broken away at the syzygy on the distal faces of the first brachials, which are a little higher and more trapezoidal in form than those of the smaller example (Pl. LIII. fig. 8). The calyx is also slightly different in outline. The expansion of the basal tube from below upwards is a trifle more rapid than in the smaller form, so that its outline is less cylindrical; while the radials are bent outwards a little at about one fourth of their height from their lower angles. This causes the calyx to appear slightly constricted at the highest level of the basiradial suture, a feature which is very marked in some varieties of the adult form.

As compared with equal sized specimens of *Rhizocrinus lofotensis*, these young individuals are distinguished by the relatively great height of the calyx, especially in the basal tube, and the expansion at the basiradial suture. The cup of *Rhizocrinus lofotensis* is not usually so high in proportion to its width; and it expands uniformly upwards, from the stem to the upper margin of the radials, so that its shape is pretty regularly obconical (Pl. IX. figs. 1, 2; Pl. X. fig. 2).

In *Rhizocrinus rawsoni*, however, the shape of the calyx varies in a most remarkable degree. It is elongated (exceeding 9 mm.) and relatively very narrow in Prof. Perrier's specimens; while in those lately dredged by Captain Cole off Panama,[2] the diameter varies between 80 and 90 per cent. of the length, which is not more than 4 mm. (woodcut, fig. 19). But as a general rule, the form of the calyx may be described as elongated and subcylindrical. In a few individuals (woodcut, fig. 19, B) it expands uniformly from below upwards throughout its whole length, as is generally the case in *Rhizocrinus lofotensis* (Pl. X. fig. 2). Sometimes the width increases very slowly and sometimes more rapidly, but there is no indication of constriction at any point in the basals or radials. In other specimens the basals expand slowly but uniformly, and the radials slope outwards more strongly, as in Pl. LIII. fig. 7. Sometimes again, the basals widen a little, but then narrow slightly till they join the radials, which slope outwards so as to again increase the diameter of the cup.

[1] Crinoïdes vivants, p. 5, Tab i. figs. 35, 39.

[2] I am indebted to Prof. F. J. Bell, F.Z.S., for calling my attention to those four remarkable specimens which are divided between the Zoological and Geological Departments at the Museum of Natural History. The keepers of these departments, Dr. A. Günther, F.R.S., and Dr. H. Woodward, F.R.S., kindly permitted me to examine them, and the former gentleman was good enough to allow the accompanying figures to be made of the two abnormal individuals under his charge.

In a considerable number of individuals from different localities on both sides of the Atlantic, I have found the radials to be marked by a circular furrow of variable depth. It crosses the body of the radial at the level of the upper angles of the basals between which the radial rests, as is well shown in the young specimen represented on Pl. LIII. fig. 8.

In the more mature individual from the Caribbean Sea, shown in Pl. IX. fig. 3, the furrow crosses the radials at about half their height; while in one of the specimens from the neighbourhood of the Azores (Station 76) the basals are much less angular at the top, so that the radials are more nearly oblong and almost entirely above a rather strong constriction at the level of the basiradial suture (Pl. X. fig. 3). Other individuals, however, are entirely destitute of any indication of such a constriction. This is the case, for example, with those dredged by Captain Cole off Panama, which are further remarkable, not only for the great relative width of the basal cup as shown in the woodcut (fig. 19), but also for the extreme variation in the position of the first pinnule.

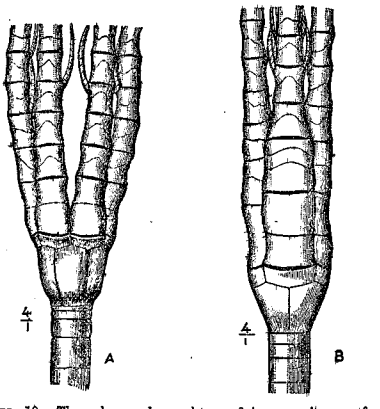


FIG. 19.—The calyx and arm-bases of two specimens of *Rhizocrinus rawsoni* from Panama; × 4. In both cases the cup is unusually wide in proportion to its height; and in the right hand specimen (B) the grouping of the lower brachials is very irregular.

In one individual this is on the epizygal of the seventh brachial in two arms, on that of the fifth in two others, and on that of the fourth in the remaining one. In four arms of another specimen the epizygals bearing the first pinnule are respectively those of the third, fourth, fourth, and fifth brachials; while in a third individual three arms are normal, with a pinnule on the third epizygal, the two others not bearing a pinnule till the next (fourth) joint. Lastly, in a fourth individual every one of the arms is developed abnormally. Three of them are shown in woodcut, fig. 19, B. I will not attempt to offer an opinion upon the grouping of the syzygies and muscular articulations in this specimen. But in one arm at least there appear to be two syzygies in succession; so that the composite brachial is in three parts instead of in two only. This is a variation of some interest, as it is normal in the arms of *Hyocrinus* (Pl. VI. fig. 1). Both types of brachial, that with one and that with two syzygies, occur in different species of the Palæozoic *Heterocrinus*, as pointed out already (*ante*, p. 53).

Although the occurrence of *Rhizocrinus rawsoni* in the East Atlantic and its more striking peculiarities, especially the length of the basals, were noticed in the first Report upon the Caribbean Crinoids[1] which Prof. Perrier quotes, he was led to describe the

[1] *Bull. Mus. Comp. Zoöl.*, vol. x., No. 4, p. 174.

"Travailleur" examples of this species as a new generic type *Democrinus*,[1] which is really, however, only a synonym of *Rhizocrinus*. His account of *Democrinus* was as follows:—"Le *Democrinus* se distingue immédiatement de tous les autres genres par la composition de son calice formé de cinq longues basales constituant à elles seules un calice en entonnoir; un sillon circulaire sépare ces cinq basales de cinq radiales rudimentaires, en forme de croissant, alternant avec elles et surmontées elles-mêmes de cinq radiales axillaires libres, rectangulaires, mobiles, sur lesquels se fixent respectivement cinq bras, beaucoup moins larges que les radiales. Ces bras se brisent très facilement au niveau de leur articulation avec les radiales axillaires qui se rabattent alors sur la voûte du calice." He further adds that in *Rhizocrinus* "les basales sont confondues et le calice formé en partie de radiales." The basals of *Rhizocrinus*, however, are very far from being "confondues," but are large and independent, as was pointed out by Pourtalès in 1868 and 1874, and by myself in 1877 and 1882. But Perrier, unaware of this fact, was unfortunately misled by the erroneous descriptions of the basals as internal and concealed which were given by Sars and Ludwig (*ante*, pp. 249–251); so that when he found a *Rhizocrinus*-like form with long and well defined basals, he naturally (though erroneously) considered it as new to science.

Although, however, the radials of *Democrinus* may be small and rudimentary externally, there is no reason why the calyx should consequently be considered as formed by the basals alone; though Perrier regards this as another character distinguishing *Democrinus* from *Rhizocrinus*. In one of the specimens of *Rhizocrinus lofotensis* which was figured by Sars[2] the radials are quite small externally; but they have large distal faces for the attachment of muscles and ligaments, the inner surfaces of which form the funnel lodging the lower part of the cœlom. The same is undoubtedly the case with the radials of *Democrinus*, to which the movable first brachials (axillaries, Perrier) are attached just as in *Rhizocrinus*.

It is difficult to understand why the radials of this type should be considered as forming part of the calyx, while those of *Democrinus* are excluded from it on account of their smaller size. On the same principle one would have to describe the cup of those species of *Antedon* in which the first radials do not appear externally, as formed by the centro-dorsal only!

Prof. Perrier describes the rudimentary radials of *Democrinus* as separated by a circular furrow from the basals below them. But a drawing of the type which he has kindly sent me, shows that while the basiradial suture is marked by five strong elevations with intervening depressions in which the radials rest, the furrow crosses the radials at the level of the highest angles of the basals. This furrow is more or less distinct in various specimens of *Rhizocrinus rawsoni* (Pl. IX. fig. 3; Pl. LIII. fig. 8), as has been pointed out already. But it can hardly be said to "separate" the radials from

[1] *Comptes rendus*, t. xcvi. p. 450.

[2] Crinoïdes vivants, Tab. ii. fig. 44.

the basals, as it crosses the former at a variable distance from their lower angles. In a few cases, however, the basiradial suture is more uniformly horizontal, and not marked by alternate elevations and depressions (Pl. X. fig. 3); so that the furrow really does indicate the line of separation between the basals and radials. But this is far from being the case in Prof. Perrier's drawing of the *Democrinus* calyx.

The fragmentary condition or absence of the arms in his specimens is nothing unusual. Only one-third of all the individuals of *Rhizocrinus rawsoni* which I have examined have any arms at all, including the young form represented in Pl. LIII. fig. 7. There may, however, be as many as one hundred and twenty joints, or rather sixty syzygial pairs, with pinnules on all but the first three or four. But they are very apt to break away at the syzygy in the first brachial, which Perrier speaks of as an articulation between a radial axillary and the lowest arm-joint. This had happened in two of his three specimens of *Democrinus*, which are "totalement dépourvus de bras; le troisième n'en présente que des restes très courts, d'après lesquels il est aisé de voir que les bras devaient être extrèmement peu développés." The drawing of this individual which he has sent me shows that its longest arm-fragment consists of only five joints, *i.e.*, two composite brachials and the hypozygal of a third. This fully accounts for the absence of pinnules, which never appear below the third epizygal in any *Rhizocrinus;* and I have little doubt that further research will prove the existence of properly developed, pinnule-bearing arms in the so-called *Democrinus*. But I do not suppose that they are quite as fully developed as those of the Caribbean variety of *Rhizocrinus rawsoni*. This has a stem more than twice the width of that of *Democrinus;* and it is generally more robust, though the calyx is distinctly shorter and broader than in Perrier's type.

The "Travailleur" specimens are of interest, both on account of their aberrant form, and because they give another locality for *Rhizocrinus rawsoni* in the East Atlantic in addition to the two discovered by the "Porcupine" in 1869; while the "Talisman" met with another locality of the type during the dredgings of 1883.[1]

It is remarkable for its close resemblance to the *Rhizocrinus londinensis* from the London Clay, isolated stem-joints of which were referred by Forbes[2] to *Bourgueticrinus*. But a well preserved and very characteristic calyx has since been discovered, and is now to be seen in the Natural History Museum at South Kensington.

[1] *Democrinus* dies hard. Perrier's mistake about the condition of the basals in *Rhizocrinus* was pointed out in the *Ann. and Mag. Nat. Hist.*, ser. 5, vol. xi., 1883, p. 334. Under these circumstances the character on which he relied as distinguishing *Democrinus* from *Rhizocrinus* became non-existent; and I therefore expressed my conviction that *Democrinus Parfaiti* and *Rhizocrinus rawsoni* were identical. Perrier, however, appears to be of a different opinion, for in the Preliminary Report of Mons. A. Milne-Edwards, the President of the "Talisman" Commission of 1883, *Democrinus* is specially mentioned as one of the captures (*Comptes rendus*, t. xcvii. p. 1392); while in the semi-official account of the collection published in *La Nature* (No. 572, p. 391) by Mons. H. Filhol, also a member of the Commission, particular reference is made to *Democrinus Parfaiti*. As the addition of a new generic type to the family Bourgueticrinidæ is of considerable importance in many ways, Prof. Perrier's revised account of its characters will be awaited with interest, both by zoologists and by palæontologists.

[2] British Tertiary Echinoderms, p. 36.

Family Pentacrinidæ, d'Orbigny, 1852.

Calyx small relatively to the stem and arms, composed of five basals and five radials, with under-basals in one genus. The rays divide from one to eight or ten times. The stem bears verticils of cirri at intervals. Two joints are united by syzygy at each node, to the upper one of which the cirri are articulated. The internodes are traversed by five ligamentous bundles which are interradially disposed and give rise to a more or less petaloid figure on the joint-faces. No root nor radicular cirri.

Remarks.—Although definitions of this family have already been given by d'Orbigny, de Loriol, and Zittel, they have been based almost entirely upon palæontological knowledge, and have not therefore given sufficient prominence to the syzygies between certain of the stem-joints, and to the ligamentous structures which produce the well known petaloid markings on their faces. The regular verticillate arrangement of the cirri along the whole length of the stem is especially characteristic of the Pentacrinidæ among the Neocrinoids, though there are a few Palæocrinoids, *e.g.*, *Belemnocrinus florifer*, in which this peculiarity presents itself. But it does not necessarily follow that the nodal joints in the stems of these older forms are the epizygals of syzygies, as is the case in the Pentacrinidæ.

The same may be said of the so-called *Encrinus beyrichi*, in which Picard has described a verticillate arrangement of the cirri on the stem, without mentioning the presence of any syzygies at the nodes.[1]

In *Apiocrinus* and *Bourgueticrinus* the upper part or even the whole of the stem is entirely free from cirri; and even when they do occur in verticils, it is only by two at a time instead of by fives, as in all the recent Pentacrinidæ except the one species *Pentacrinus alternicirrus* (Pl. XXV.; Pl. XXVII. figs. 1–3). Further, there is nothing like a syzygy between the two joints forming a node in a *Bourgueticrinus*-stem, which are articulated to one another in the usual way.

It is in fact the characters of the stem, much more than those of the calyx, which constitute the special distinctive mark of the Pentacrinidæ. For although *Extracrinus* is known by its under-basals, the composition of the calyx is identical in *Millericrinus* and *Pentacrinus*, and also in *Metacrinus*, if we follow strict morphology and consider the second radials as really arm-joints.

The calyx of *Balanocrinus* is unfortunately not yet known. The genus was founded by Agassiz for a fragment in the Basle Museum, which he supposed to be a peculiar form of calyx. But de Loriol[2] has shown that "ce prétendu calice n'est qu'un fragment de tige attaqué et deformé par un parasite." Agassiz had, however, referred the stems associated with it to *Pentacrinus subteres;* and de Loriol, finding that the stem-joints of

[1] Ueber eine neue Crinoiden-Art aus dem Muschelkalk der Hainleite bei Sondershausen, *Zeitschr. d. deutsch. geol. Gesellsch.*, Jahrg. 1883, p. 201.

[2] Swiss Crinoids, p. 163.

this type really are different from those of other Pentacrinidæ, has re-established the genus *Balanocrinus* upon them. The five sectors of each more or less circular face have no ridges or denticulations along their sides, those being limited to the outer margin of the joint-face. They are usually therefore of greater size than the corresponding parts on the stem-joints of *Extracrinus* and *Pentacrinus*, which are sometimes much constricted by the development of ridges at their sides. The stem-joints of *Balanocrinus*, therefore, are somewhat like those of *Millericrinus;* though in the latter type the whole joint-face is uniform in character, and not marked out into sectors as is the case in the Pentacrinidæ. Many Palæocrinoids have joints somewhat like those of *Balanocrinus*, *i.e.*, crenulated round the edge, but nothing more. The genus commenced with *Pentacrinus* in the Trias, and survived to the Lower Neocomian, no remains of it having yet been found at any higher horizon; while I have not met with this simple form of stem-joint in any recent species.

Owing to the deficiency of our knowledge respecting the nature of the calyx of *Balanocrinus*, I have found it necessary to use the characters of the stem as the basis of the classification of the family. *Balanocrinus* may have under-basals like *Extracrinus*, or more than three radials like *Metacrinus;* but until we know more about its calyx a classification of the Pentacrinidæ must depend primarily upon the varying features of the stem.

I. Five to eight large teeth at the sides of each petaloid sector, most of which start from the outer edge of the joint-face, while the remainder meet their fellows in the interpalmar spaces.
  1. Three radials, ... *Pentacrinus.*
  2. More than three radials, ... *Metacrinus.*

II. Sectors linear with delicately crenulated edges. Under-basals. The first radials much prolonged downwards. Secondary arm-trunks each bear a succession of armlets on the same side, *Extracrinus.*

III. Joint-faces crenulated round the edge only, not along the sides of the sectors, . *Balanocrinus.*

Three other supposed genera have also been referred to this family. One is *Isocrinus*, von Meyer,[1] of which the stem is scarcely known; while it is probable that von Meyer's description of the primary rays as consisting of but two joints, basals being likewise wanting, is also somewhat incorrect. The mode of division of the rays, on which von Meyer laid considerable stress, is perfectly normal. I prefer therefore to refer the type, temporarily at any rate, to the genus *Pentacrinus*, as has been done by Bronn and others, though I will not attempt to follow them into specific details.

Another unrecognised genus of the Pentacrinidæ is the *Chladocrinus* of L. Agassiz.[2] After defining the stem of *Pentacrinus* as "portant de distance en distance des rayons simples verticillés," he continued, "on pourra désigner sous le nom de *Chladocrinus* les espèces dont les rayons accessoires forment des verticillés plus ou moins distans."

[1] *Isocrinus* und *Chelocrinus*, Museum Senckenbergianum, Frankfurt, 1837, p. 251.

[2] Prodrome d'une Monographie des Radiaires ou Echinodermes, *Mém. de la Soc. des Sci. Nat. de Neuchatel*, t. i., 1835, p. 194.

No further definition of *Chladocrinus* was ever given by Prof. L. Agassiz; and it is not surprising therefore that the genus has never been accepted by naturalists. The remaining type which is supposed to be generically distinct from *Pentacrinus*, is the *Cainocrinus* of Forbes.[1] It has recently been revived by de Loriol;[2] but since it was based on a misconception, and its only distinctive character depends upon a feature which is very variable among the recent species, viz., the presence or absence of a closed ring of basals, I see no good in retaining it (see pp. 281–283). Practically, therefore, owing to the well marked characters of *Extracrinus* and our want of knowledge of *Balanocrinus*, a definition of *Pentacrinus* for the study of recent forms need only emphasise those points in which it differs from *Metacrinus*. I have, however, referred to one or two characters in which the genus differs from *Extracrinus*.

Genus *Pentacrinus*, Miller, 1821.[3]

1761. *Palmier marin*, Guettard, Mémoires de Mathématique et de Physique tirés des Registres de l'Academie Royale des Sciences, de l'année MDCCLV., Paris, 1761, p. 225.
1762. *Encrinus*, Ellis, Phil. Trans., vol. lii. pt. i. for the year 1761, London, 1762, p. 358.
1766. *Isis*, Linnæus, Systema Naturæ, ed. xii., Holmiæ, 1766, t. i. p. 1288.
1816. *Encrinus*, Lamarck, Histoire Naturelle des Animaux sans Vertébres, t. ii., Paris, 1816, p. 432.
1820. *Pentacrinites*, von Schlotheim, Die Petrefactenkunde, Gotha, 1820, p. 327.
1821. *Pentacrinus*, Miller, A Natural History of the Crinoidea, Bristol, 1821, p. 45.
1832. *Pentacrinites*, Goldfuss, Petrefacta Germaniae, Dusseldorf, 1832, t. i. p. 168.
1832. *Solanocrinites*, Goldfuss, *Ibid.*, p. 168.
1834. *Pentacrinus*, de Blainville, Manuel d'Actinologie, Paris, 1834, p. 257.
1834. *Encrinus*, de Blainville, *Ibid.*, p. 254.
1835. *Pentacrinus*, Agassiz, Mém. de la Soc. d. Sci. Nat. de Neuchatel, t. i. p. 194.
1835. *Chladocrinus*, Agassiz, *Ibid.*, p. 195.
1836. *Pentacrinus*, Buckland, Geology and Mineralogy, London, 1836, vol. i. p. 432.
1837. *Isocrinus*, von Meyer, Museum Senckenbergianum, Frankfurt, ii. p. 251.
1843. *Pentacrinus*, Müller, Abhandl. d. k. Akad. d. Wiss. Berlin, Jahrg. 1841, p. 177.
1845. *Pentacrinus*, Austin, A Monograph on Recent and Fossil Crinoidea, Bristol, 1843–45, p. 110.
1845. *Pentacrinus*, Desor, Bull. Soc. d. Sci. Nat. de Neuchatel, vol. i. pp. 213, 214.
1845. *Isocrinus*, Desor (*non* von Meyer), *Ibid.*, p. 213.
1845. *Balanocrinus*, Agassiz (*non* de Loriol), in Desor, *Ibid.*, p. 214.
1847. *Pentacrinus*, d'Orbigny, Cours élément. de Paléontol. et de Géol. stratigr., t. ii. Fasc. 1, Paris, 1852, p. 149.
1852. *Isocrinus*, d'Orbigny, *Ibid.*, p. 149.

[1] British Tertiary Echinoderms, p. 33.

[2] Swiss Crinoids, pp. 111, 112.

[3] The above list contains, I believe, all the most important references to the recent *Pentacrinus* since the time of Guettard, together with notices of the chief palæontological works in which this type and its fossil representatives are mentioned. But it makes no pretence whatever of recording all the various names which have been bestowed at different times upon fragments of fossil Pentacrinidæ. A task of this kind is scarcely worth undertaking, as the result would be totally incommensurate with the labour involved.

1852. *Pentacrinus*, Forbes, Monograph of the Echinodermata of the British Tertiaries, p. 33.
1852. *Cainocrinus*, Forbes, *Ibid.*, p. 34.
1857. *Pentacrinus*, Pictet, Traité de Paléontologie, 2me éd., Paris, 1857, t. iv. p. 342.
1857. *Isocrinus*, Pictet, *Ibid.*, p. 344.
1857. *Comatula* (pars), Pictet, *Ibid.*, p. 288.
1862. *Pentacrinus*, Dujardin and Hupé, Hist. Nat. des Zoophytes, Échinodermes, Paris, 1862, p. 179.
1864. *Cenocrinus*, Wyv. Thoms., The Intellectual Observer, August 1864, p. 3.
1864. *Neocrinus*, Wyv. Thoms., *Ibid.*, p. 7.
1864. *Pentacrinus*, Lütken, Videnskabelige Meddelelser fra den naturhistoriske Forening i Kjöbenhavn, 1864, Nr. 13–16, p. 207.
1872. *Pentacrinus*, Wyv. Thoms., Proc. Roy. Soc. Edin., vol. vii. p. 765; and The Depths of the Sea, p. 435.
1875. *Pictetocrinus*, de Loriol, Monographie Paléontologique et Géologique des Étages Supérieurs de la formation Jurassique des Environs de Boulogne-sur-Mer, 2me partie, p. 297.
1876. *Pentacrinus*, Quenstedt, Petrefactenkunde Deutschlands, Bd. iv.; Asteriden und Encriniden, p. 186.
1879. *Pentacrinus*, de Loriol, Monographie des Crinoïdes fossiles de la Suisse, p. 114.
1879. *Cainocrinus*, de Loriol, *Ibid.*, p. 111.
1879. *Pentacrinus*, Zittel, Handbuch der Palæontologie, Palæozoologie, München und Leipzig, 1876–1880, Bd. i. p. 393.
1880. *Pentacrinus*, P. H. Carpenter, Journ. Linn. Soc. Lond. (Zool.), vol. xv. p. 210.
1882. *Pentacrinus*, P. H. Carpenter, Bull. Mus. Comp. Zoöl., vol. x. p. 167.
1884. *Pentacrinus*, P. H. Carpenter, Proc. Roy. Soc. Edin., vol. xii. p. 355.

A. *Characters of the Genus.*

The petaloid sectors on the faces of the stem-joints are bordered by a few large ridges, of which the smaller proximal ones meet those of adjacent sectors in the interpetaloid spaces, while the large distal ridges reach the outer edge of the joint. The supranodal joints are scarcely modified for the cirrus-sockets, and the articular facets rarely reach the upper edges of the nodal joints.[1] The cirri consist of from twenty to fifty joints, and vary considerably both in length and in appearance.

The basals may be very small knobs, or form a complete ring, and have but a slight tendency to downward extensions of their lower angles. There are never more than three radials, none of which bear pinnules.

The rays may divide five times, but rarely more than thrice; and their subdivisions are equal in value or nearly so. The basal joints of the lower pinnules are usually rather broad and flattened laterally, with sharp dorsal edges.

Remarks.—The genus *Pentacrinus* is generally, and with good reason, attributed to Miller. But a few authors have associated with it the name of von Schlotheim.[2] It is true that this able palæontologist used *Pentacrinites* as a generic name a year before the publication of Miller's classical monograph; but he made no attempt to define it as Miller did, nor did he give diagnoses of any of the species which he referred to the genus. In

[1] In several fossil species, however, the cirrus-facets take up the whole height of the nodal joints.
[2] Die Petrefactenkunde, Gotha, 1820, p. 327.

fact, the first of these, *Pentacrinites vulgaris*, designates a fossil type to which he also referred (under the name of *Encrinus caput-Medusæ*) the recent specimens described by Guettard and Ellis. These were subsequently referred by Miller to his *Pentacrinus caput-Medusæ* (=*Pentacrinus asterius*, Linn, sp.); and the type was eventually rendered classical by the researches of Müller. Under these circumstances I see no reason for departing from the practice of d'Orbigny, Forbes, Pictet, de Loriol, and Zittel, and have therefore attributed the genus to Miller, with the date 1821. When establishing it, he simply converted into a generic designation the name which had long been commonly employed for fragments of stems with the characteristic petaloid markings on their terminal faces. Miller's generic diagnosis of this type, like those of the numerous other Crinoids described by him, corresponds to the definition of a family, when considered by the help of our present knowledge.

Five species were established by Miller[1]—(1) the recent *Pentacrinus caput-Medusæ* from the West Indies; (2) the two fossil species from the Lias, *Pentacrinus briareus* and *Pentacrinus subangularis;* and (3) two other fossils which need not be considered here. Although apparently taking the single recent species then known as the type of the genus, he gave a generic diagnosis which represents, although imperfectly, the dissected calyx of one of the two Liassic species. These have the radials prolonged downwards over the upper stem-joints between and below the outer ends of the basals; and the Messrs. Austin consequently proposed to establish the new genus *Extracrinus* for their reception, while restricting *Pentacrinus* to species having the general character of the recent *Pentacrinus caput-Medusæ* (=*Pentacrinus asterius*, Linn, sp.).

Miller described the "pelvis" of the fossil *Pentacrinus briareus* and *Pentacrinus subangularis* as similar in character to that of the recent *Pentacrinus asterius*, namely, as consisting of five small and nearly cuneiform basals in contact by their central ends. The Messrs. Austin, in accordance with their peculiar method of nomenclature, gave the name "dorsocentral plate" to the pelvis of Miller (basals, Müller); and they described that of *Pentacrinus asterius* as "resembling an enlarged and thickened supracolumnar joint," without divisions, the salient angles of which alternate with the five first radials, or, as they called them, the first series of perisomic pieces. The pelvis of the three fossil species *Pentacrinus johnsoni, Pentacrinus tuberculatus*, and *Pentacrinus milleri*, was described as closely resembling that of *Pentacrinus asterius;* but in their diagnoses of *Extracrinus briareus* and *Extracrinus subangularis* they differed considerably from Miller and Goldfuss. They gave the name dorsocentral plate, not as usual to the pelvis of Miller as in *Pentacrinus asterius*, but to five small and nearly concealed pieces which are placed beneath the true pelvis, and were unknown to Miller. They are radial in position, and not interradial like the pieces described by Miller and Goldfuss as composing the pelvis of these two Liassic species. These, the true basals, which thus alternate with

[1] A Monograph on Recent and Fossil Crinoidea, Bristol, 1843–45, p. 95.

the elements of the so-called dorsocentral plate, were described by the Messrs. Austin as "solid pointed pieces, whose points pass outward, and rest on the salient angle of the pentagonal column," precisely, in fact, like the rays of the stellate dorsocentral plate or pelvis of *Pentacrinus asterius*, with which Miller had rightly regarded them as homologous. The Messrs. Austin, however, supposed Miller to have been in error upon this point, as they believed the so-called dorsocentral plate of *Extracrinus* to be homologous with that of *Pentacrinus*, not paying any attention whatever to its position with regard to the radial symmetry of the animal. Neither did they notice that in *Pentacrinus* the five elements composing the dorsocentral plate are perforated by bifurcating canals, which occur in *Extracrinus*, not in the component pieces of the dorsocentral plate, but in those of the next series, the pelvis of Miller; and they were consequently led to regard these last, the basals of Müller, as representing the first series of perisomic plates (or the first radials, Müller) of *Pentacrinus*; while the first radials of *Extracrinus*, alternating in position with the basals, were described by them as a second series of lateral or perisomic pieces which are unrepresented in *Pentacrinus*. The fact is, however, that it is the dorsocentral plate of the former genus which is not represented in *Pentacrinus*, the pelvis of which represents the so-called first series of perisomic plates in *Extracrinus*, as was rightly supposed by Miller. The two sets of plates are precisely similar in their position relatively to the radial symmetry of the animal and in being perforated in the same way by bifurcating canals. These two important points, which were entirely left out of consideration by the Messrs. Austin, demonstrate the homology of the first series of perisomic plates in *Extracrinus*, not only with the pelvis or dorsocentral plate of *Pentacrinus*, but also with the outer circlet of basals in *Encrinus*; while the five small, nearly concealed pieces forming the so-called dorsocentral plate of *Extracrinus*, which alternate with the true or outer basals, obviously represent the inner circlet of basals of *Encrinus*. The Messrs. Austin were fortunate enough to obtain a specimen of *Extracrinus briareus* showing the interior of the calyx, the centre of the floor of which is occupied by the five small, radially placed elements of the so-called dorsocentral plate; and the resemblance in every respect between these and the inner circlet of basals in *Encrinus* is so close as to leave little doubt that they are homologous with one another.

It is therefore somewhat striking to find that the extensive downward prolongation of the first radials over the upper stem-joints, which is the chief characteristic of *Extracrinus*, as defined by the Messrs. Austin, is also found, though to a smaller extent, in *Encrinus*, as pointed out by Beyrich. *Encrinus*, like *Extracrinus*, has a dicyclic base; but the same tendency to downward prolongation of the radials is seen in *Pentacrinus naresianus* (Pl. XXX. fig. 1) and more distinctly in *Metacrinus* (Pl. XXXIX. fig. 1; Pl. XLIX. fig. 2).

The Austins' genus *Extracrinus* has not met with the attention which it deserved,

possibly on account of the clumsy nomenclature adopted by these authors. Ramsay, Phillips, and Etheridge have used it in this country; but the well known German palæontologist Quenstedt,[1] who has probably seen it in greater abundance than any other naturalist, speaks of it in a decidedly scoffing tone. This, however, is only to be expected from one who does not separate *Bourgueticrinus* from *Apiocrinus*. Zittel mentions Austin's name, but without committing himself to an acceptance of it; and I have reason to believe that M. de Loriol is prepared to accept the genus after it has been redefined in a manner which is consistent with the present state of our knowledge.

The genus *Extracrinus*, which includes the two groups "Briariden" and "Subangularen" of Quenstedt, is thus distinguished by the presence of under-basals (dorsocentral plate, Austin) and the downward prolongation and jointing of the radials. But it also differs very markedly from the Post-Liassic and recent Pentacrinites in the characters of its stem and arm-divisions.

The precise structure of the stem of *Extracrinus*, *i.e.*, the relations of its nodal and internodal joints, has yet to be worked out. Some fragments of stem, probably from near the top, seem to consist entirely of nodal joints; while in others there are several joints between any two whorls of cirri, just as in the ordinary Pentacrinites. The joint-faces of *Extracrinus*, however, are very different from those of *Pentacrinus*. In the latter genus, the five petaloid figures indicating the position of the stem ligaments are more or less oval in shape, pointed at one or both ends, and bounded by strong ridge-like processes, with alternating furrows (Pl. XIII. figs. 2–6, 9–11; Pl. XXII. figs. 13, 14, 22; Pl. XXX. figs. 25–30; Pl. XXXa. fig. 7; Pl. XXXII. fig. 3; Pl. XXXVII. fig. 22). There may be only about three of these on each side of the petal, as in most recent forms, or there may be from six to twelve of a smaller size. But all of these ridges, except those most centrally placed, slant inwards from the edge of the joint, where their outer ends cause the denticulation which is so marked in all but the oldest specimens (Pl. XIX. figs. 2–5; Pl. XXVII. fig. 1; Pl. XXXa. fig. 6; Pl. XXXI. fig. 3; Pls. XXXV., XXXVI.).

In *Extracrinus*, however, the five interradial petals are quite narrow, and much less distinctly oval than in *Pentacrinus*, sometimes being linear with rounded outer ends. Even when the joints are stellate the petals do not occupy more than the central portion of each ray of the star, instead of the whole of it as in *Pentacrinus*; and when the joints are pentagonal or circular there is a more or less triangular space between every two petals, which is plain and devoid of sculpture. Then again the markings at the sides of the petals are much more delicate than in *Pentacrinus*, having more the character of striæ or crenulation than of coarse ridges. They are also much more numerous than in *Pentacrinus*, and are strictly limited to the sides of the petals, not reaching the outer edge of the joint. These characters are well shown in several of the figures published

[1] Encriniden, p. 270.

by different palæontologists, *e.g.*, on pl. 53 of Buckland's Geology and Mineralogy, figs. 9–13; on Tab. 101 of Quenstedt's Encriniden, especially figs. 24, 27, 33, and 37; and also on pl. 12 of the Messrs. Austin's Monograph, figs. *d*, *f*, *k*, *n*, *o*, *r*. None of these authors, however, seem to have noticed the distinction of this type of joint from that of the ordinary Pentacrinidæ, either recent or fossil; and attention was first drawn to it by de Loriol, as will be pointed out subsequently.

In the ordinary Pentacrinidæ, as in the multiradiate Comatulæ, there is no special regularity in the mode of division of the secondary and tertiary arms. The twenty secondary arms borne upon the distichal axillaries may either remain simple, or fork again, once or oftener. But in most cases the forking is very irregular. Secondary (palmar) axillaries may appear upon any of the four secondary arms; and the two tertiary arms borne by them are of equal size, and have equal power of forking again, though as a rule they do not all do so. A good instance of this is shown in Miller's figure [1] of *Pentacrinus asterius* (*caput-Medusæ*), which is represented more diagrammatically in Quenstedt's Tab. 97, fig. 3. A similar arrangement has been described by Lütken in *Pentacrinus mülleri*,[2] while it also occurs in *Pentacrinus maclearanus*, *Pentacrinus wyville-thomsoni*, and *Pentacrinus alternicirrus* (Pl. XIV.; Pl. XV. fig. 1; Pl. XIX. fig. 2; Pl. XXV.; Pl. XXVI. fig. 4). In all these cases the secondary (and tertiary) axillaries are limited to the outer arms of each successive pair, so that the arrangement of the arms on the ray is 2, 1; 1, 2; or 2, 1, 1; 1, 1, 2.[3] But the two (or four) inner arms are equivalent to the outer ones in all respects, neither of them dividing again.

While the arm-division in *Extracrinus* proceeds to a much greater extent than in *Pentacrinus*, it is confined as a rule to the sides of the ray, only the outer arm of each successive pair bearing axillaries, just as in the secondary and tertiary arms of *Pentacrinus asterius*, *Pentacrinus mülleri*, &c. The four tertiary arms which spring from each pair of palmar axillaries are rarely of equal size, and never absolutely equivalent. The two inner ones are usually rather the smaller, and except in some forms of *Extracrinus subangularis* do not divide again. Each of the larger outer arms, however, divides again after a few joints, but the division is unequal. The smaller inner face of the axillary, *i.e.*, that turned towards the other axillary, bears a slender armlet; while the main arm-trunk is continued directly onwards without change of direction. It gradually diminishes in size, and gives off at short intervals a series of slender armlets from its inner side, but it never really forks. But for the pinnules borne by it and its subordinate armlets, one would be almost inclined to say that the distichal axillary bears two secondary arms which have long slender pinnules placed at intervals upon their adjacent inner faces, but none whatever upon their outer sides. These organs are real

[1] *Op. cit.*, p. 48, pl. i. [2] Om Vestindiens Pentacriner, *loc. cit.*, pp. 203, 204.

[3] The Caribbean *Antedon spinifera* often shows exactly the reverse condition to this. Palmar axillaries are frequently only developed on the inner pair of the four secondary arms, so that the grouping on each ray is 1, 2; 2, 1.

arms, however, for they bear the pinnules as their larger fellows do; and in some forms the lowest of them (tertiary arms) have a series of unequal axillaries and bear armlets on their inner faces just as the large outer arms do. In such individuals these inner tertiary arms are more equal in size to the outer pair. The two extreme types are well represented on Tab. 97 of the Encriniden, figs. 5 and 6, by Quenstedt, who partially founds upon them the distinction between the "Briariden" and the "Subangularen." In the former group the inner tertiary arms are undivided armlets like those which come off farther out on the ray; while the inner tertiary arms of the Subangularen, though smaller than the outer ones, bear armlets on their inner faces, which correspond to those on the inner faces of the outer arms that spring from the same axillaries.

Owing to the presence of these armlets on the inner tertiary arms, the Subangularen generally have the "finger-reichsten Krone" as pointed out by Quenstedt. This is not always the case, however, for in a specimen from the *Posidonia*-beds of Holzmaden, which is figured by him,[1] the inner tertiary arms are undivided, and their successors are more equal to the outer arms of the ray than in some forms of *Extracrinus briareus*.

Under the name of *Pentacrinus briareus minutus*, Quenstedt[2] has figured a curious little species in which the division of the arms seems to be somewhat irregular, and the distinction of arms and armlets less marked than is usually apparent in *Extracrinus*. But I do not think that this variation, even if it be established, need have much effect upon the stability of *Extracrinus* as a generic type.

The differences between the Liassic and the recent Pentacrinidæ on which the genus was founded by the Messrs. Austin were at first regarded by the late Sir Wyville Thomson as of merely subgeneric value. Believing that *Pentacrinus briareus* "seems to have a just claim to be recognised as the type of the genus *Pentacrinus*," he introduced the name *Cenocrinus* for the *Pentacrinus caput-Medusæ* of Müller, and one or two fossils which closely resemble it.[3] He subsequently abandoned this name, however, and referred the type to *Pentacrinus* as all later writers have done, some recognising *Extracrinus* as a separate genus and some not. The Messrs. Austin[4] pointed out that Miller "in his arrangement of the Crinoidea has taken the *Pentacrinus caput-Medusæ* for the typical species, while at the same time his generic plate represents the dissected skeleton of quite a different Crinoid. In the hope to remedy this intermingling of genera, we propose to retain Miller's genus *Pentacrinus*, and to continue the *Pentacrinus caput-Medusæ* as the type of the genus;" while the name *Extracrinus* was proposed for the Liassic *Pentacrinus briareus* and *Pentacrinus subangularis*. This arrangement seems decidedly preferable to that proposed by Sir Wyville, who eventually gave up *Cenocrinus* as a subgenus; though I cannot learn that he ever formally adopted *Extracrinus*.

A second subgenus of *Pentacrinus* besides *Cenocrinus* was also proposed by Sir

[1] Encriniden, Tab. 101, fig. 1.
[2] *Ibid.*, Tab. 99, fig. 177.
[3] Sea Lilies, *The Intellectual Observer*, August 1864, p. 3.
[4] Monograph, p.

Wyville in 1864,[1] the type being a new West Indian species which he designated as *Pentacrinus* (*Neocrinus*) *decorus*. The differences between this type and *Pentacrinus asterius* (*caput-Medusæ*) are undoubtedly considerable, as I have expressed by separating the two as far as possible in my arrangement of the species (see p. 299). But they are rather physiological than morphological in character, and one or two errors of observation have caused them to appear greater than they really are. There are syzygies below the nodal joints of *Pentacrinus asterius* (Pl. XIII. figs. 3, 5, 8), just as in *Pentacrinus decorus* (Pl. XXXVI.; Pl. XXXVII. figs. 5–8, 12, 19, 21); so that although the stem of the former species is very strong and rigid, it can hardly be said to be distinguished by the "absence of all provision for its rupture," such as Sir Wyville[2] described in the more slender stem of *Pentacrinus decorus*.

The supposed difference between the disks of *Pentacrinus asterius* and *Pentacrinus decorus*, which was founded on a belief in the presence of tooth-like oral plates in the former genus, is also due to error, owing to the unsatisfactory condition of Michelin's specimen, which was said to possess these embryonic structures. Sir Wyville recognised this subsequently when he obtained a spirit specimen of *Pentacrinus asterius*, the disk of which he described as follows:[3]—"The perisome of the disk is covered with irregular calcareous plates, and at the free inner angles of the interradial spaces these plates become closer, and form a solid kind of boss; but there are no distinct oral plates." On the other hand, the disk of *Pentacrinus decorus*[4] (Pl. XXXIV. fig. 2) could hardly be called "comparatively unprotected" as distinguished from that of *Pentacrinus asterius*, which Sir Wyville described on the previous page as "uniformly defended and plated with calcareous pavement."

In the nature of the arms, however, there is a considerable difference between the two types, as was well described by Sir Wyville. Those of *Pentacrinus asterius* are "greatly multiplied, large and strong. No syzygies, save those at the base, which can be used on an emergency, tend to diminish their strength, an arrangement essential to the full supply of food in their fixed condition." On the other hand, in *Pentacrinus decorus* the number of arms is "greatly less, and the arms are provided throughout with syzygies, an arrangement apparently suitable to its greater liability to trivial accidents in its free condition." He went on to say, "At first I had some doubt as to the propriety of making this species the type of a new subgenus, and any one of the above characters would certainly not have afforded sufficient grounds; but all these characters taken together form a remarkably compact assemblage, which places *Neocrinus* in a directly intermediate position between *Cenocrinus* and *Comatula*." Two of the principal points of difference between *Cenocrinus* and *Neocrinus* have, however, no foundation in fact, while a third is, at most, one of specific value; and the fourth, the supposed difference in the mode of

[1] Sea Lilies, *The Intellectual Observer*, August 1864, p. 7. [2] *Ibid.*, p. 10.
[3] *Proc. Roy. Soc. Edin.*, vol. vii., 1872, p. 766. [4] Sea Lilies, *The Intellectual Observer*, August 1864, p. 11.

life, is valueless. For individuals of *Pentacrinus decorus* have been found attached to telegraph cables by a spreading base; and one specimen of *Pentacrinus asterius* at any rate, which I have seen, had the stem broken at a nodal joint, which was worn and rounded below, its central canal being closed up by a small median tubercle; while this condition is common to several other Pentacrinidæ, as I have pointed out already (*ante*, pp. 18–22).

Apart from the length of the internodes and the characters of the stem-joints, cirri, and arms, all of which are merely of specific value, the chief difference between *Pentacrinus asterius* and *Pentacrinus decorus* is in the mode of union of the two outer radials. In the latter type, as shown in Pl. XXXIV. figs. 3 and 5 (which were drawn under Sir Wyville's own direction), these joints are united by a bifascial articulation. But in *Pentacrinus asterius* (Pl. XII. figs. 18 and 21), and also in *Pentacrinus mülleri* and *Pentacrinus wyville-thomsoni* (Pl. XVIII. figs. 8, 11), there is a syzygy in this position. This difference, however, is one which occurs continually among the numerous species of the Comatulid genera. *Antedon rosacea* and *Actinometra meridionalis* are types of many species having the bifascial articulation; while *Antedon fluctuans*[1] and *Actinometra solaris* represent a smaller number of species which have the syzygy. I see no reason, therefore, for considering this difference as one of subgeneric value among the Pentacrinidæ, so as to separate *Pentacrinus decorus*, together with *Pentacrinus blakei* and *Pentacrinus naresianus* under a separate name, *Neocrinus*, from the other five species which have a syzygy between the two outer radials. Four of these, and probably *Pentacrinus asterius* as well, become free at a certain period of their life, just as Sir Wyville discovered to be the case in *Pentacrinus decorus;* so that one of the physiological characters on which he relied as giving *Neocrinus* an intermediate position between *Pentacrinus asterius* and the Comatulæ is of much more general occurrence than he supposed.

The separation of *Pentacrinus asterius* and *Pentacrinus decorus* as types of subgenera appears to have been abandoned by Sir Wyville within a year after he had proposed the name *Cenocrinus* for the former species. For in his well known memoir On the Embryogeny of *Antedon rosaceus*, published in the Philosophical Transactions for 1865, frequent reference is made to *Pentacrinus* (*Neocrinus*) *asterias* as well as to *Pentacrinus* (*Neocrinus*) *decorus;* while Oersted's species *Pentacrinus mülleri* was also referred to the subgenus *Neocrinus*. Sir Wyville seems, therefore, still to have regarded *Pentacrinus briareus* as having the first claim to the generic name *Pentacrinus*, although the Messrs. Austin had expressed an opposite opinion. He appears, however, to have eventually adopted their view, as all later writers have done. For in The Depths of the Sea reference is made to two West Indian species only, viz., *Pentacrinus asterius* and *Pentacrinus mülleri;*[2] and neither *Neocrinus* nor *Cenocrinus* is mentioned, while *Pentacrinus decorus* is confused with *Pentacrinus mülleri*. Subsequently also, when describing new

[1] The specific formula of this type is—A.R. 3 . 2 . 2 . $\frac{b}{b}$.

[2] The Depths of the Sea, pp. 436, 442, 1873.

"Porcupine" and Challenger species, Sir Wyville named them *Pentacrinus wyville-thomsoni* and *Pentacrinus macleæranus;* and the plate which was drawn under his supervision was lettered *Pentacrinus asteria* (Pl. XI.).

We may therefore feel tolerably certain that Sir Wyville had recognised the inexpediency of limiting the name *Pentacrinus* to the Liassic species only, though their generic differences from the recent Pentacrinidæ had been noticed by him.

We have seen that the name *Cenocrinus*, which was applied by Sir Wyville in 1864 to the classical species *Pentacrinus caput-Medusæ* of Miller and Müller, was afterwards dropped by him; but I cannot make out whether or not this arose from his becoming acquainted with the genus *Cainocrinus* which had been established twelve years previously by Forbes.[1] The essential difference between this type and *Pentacrinus*, as defined by Forbes, is that the pelvis or basal ring of *Pentacrinus* is "composed of a single piece formed out of five anchylosed plates," while that of *Cainocrinus* is "formed out of five free plates." These are seen in Forbes's figure to compose a closed basal ring which separates the radials from the top stem-joint; and this is not the case with the basals either of *Extracrinus* or of *Pentacrinus asterius*, the only recent species known to Forbes.

What Sir Wyville thought of Forbes's genus I cannot say. He never referred to it, and the fact of his having himself proposed *Cenocrinus* as a subgeneric type looks rather as if he had not been previously acquainted with *Cainocrinus*. In any case, however, whether he knew it or not, he still referred to the same genus *Pentacrinus*, the species which was dredged by the "Porcupine" in 1870, and was named after himself by his colleague Dr. Gwyn Jeffreys,[2] F.R.S.; and this is in all respects a true *Cainocrinus* with a closed basal ring (Pl. XIX. figs. 6, 7; Pl. XX. figs. 1–3). Quenstedt[3] was unable to see any essential difference between *Cainocrinus* and *Pentacrinus*; but de Loriol,[4] writing about the same time, took a different view. Unaware of Forbes's genus, he proposed to establish a new genus *Picteticrinus* for a fossil species of *Pentacrinus* presenting the then unusual character of a closed basal ring. But he subsequently discovered this to be a feature of the type described by Forbes as *Cainocrinus*, which he adopted as a generic name instead of *Picteticrinus*;[5] and he referred to this type a species that had been originally supposed by Desor[6] to belong to von Meyer's genus *Isocrinus*, which has been discussed above (*ante*, p. 271). *Cainocrinus* was regarded by de Loriol as establishing a transition between *Millericrinus* and *Pentacrinus*. He defines *Pentacrinus* as differ-

[1] Monograph of the Echinodermata of the British Tertiaries, pp. 33, 34.

[2] *Proc. Roy. Soc. Edin.*, vol. vii., 1872, p. 767; and also The Depths of the Sea, p. 444.

[3] Encriniden, p. 269.

[4] Monographie Paléontologique et Géologique des Étages Supérieurs de la formation Jurassique des Environs de Boulogne-sur-Mer, 2me partie, p. 297.

[5] Swiss Crinoids, p. 111.

[6] Notice sur les Crinoïdes suisses, *Bull. Soc. d. Sci. Nat. de Neuchatel*, vol. i. p. 53.

ing from *Millericrinus* in the verticillate arrangement of the cirri, and in having very small basals, which do not meet externally. Thus he says "pièces basales fort petites, en général arrondies, non contiguës et reposant sur les cinq angles de la tige." On the other hand, *Cainocrinus* has a complete ring of basals like *Millericrinus*, but a stem with verticils of cirri like *Pentacrinus*. I cannot, however, regard this classification as satisfactory; for even in those species of *Pentacrinus* which have an incomplete basal ring there is a great amount of variation in the extent to which the central ends of the basals are joined, and in the size of their outer ends which appear between the radials and the top stem-joint (Pl. XI.; Pl. XII. fig. 16; Pl. XIII. fig. 1; Pl. XIV; Pl. XV. figs. 1, 2; Pls. XXVIII., XXIX.; Pl. XXX. figs. 1, 4; Pl. XXXI. figs. 1, 2; Pl. XXXIV. figs. 1, 8; Pls. XXXV., XXXVI.; Pl. XXXVII. figs. 1, 2). I have elsewhere stated my reasons for not adopting *Cainocrinus* as a genus distinct from *Pentacrinus*;[1] and the results of my examination of the large series of Pentacrinidæ dredged by the Challenger and the "Blake" Expeditions has only served to strengthen my opinion. It must be remembered that the question of the more or less perfect closure of the basal ring simply has reference to its appearance on the exterior of the calyx. The inner ends of the basals always meet one another around the neurovascular axis. But they are sometimes not in contact by the whole length of their sides, so that their outer ends appear to be separated by the radials (compare Pl. XII. figs. 1, 2, 16; Pl. XIII. fig. 1; Pl. XIX. figs. 6, 7; Pl. XX. figs. 1–3; Pl. XXVI. fig. 11; Pl. XXX. figs. 1, 4; Pl. XXXIV. figs. 1, 8; Pl. XXXVI.).

The closure of the basal ring, therefore, is so extremely variable within specific limits that it scarcely affords characters of specific, much less of generic value.

So far as the fossil species are concerned, however, it is quite possible that the more or less perfect closure of the basal ring on the exterior of the calyx may afford characters of some systematic value. But I strongly suspect that the examination of a large series of specimens would indicate a very great variability in the size of the basals, just as in the recent types.

The unique specimen of *Pentacrinus maclearanus* (Pl. XVI.) has a closed basal ring, and would therefore be called a *Cainocrinus* by de Loriol. In *Pentacrinus wyville-thomsoni* there is sometimes a very close union between the pentagonal basals as in Pl. XIX. figs. 6, 7, and Pl. XX. figs. 1–3; while in other specimens the basals are more triangular in shape and less closely united, as is shown, with a little exaggeration, in Pl. XVIII. figs. 1, 2. It occasionally happens that one or two of the basals fail to meet their fellows, but the ring is always more or less complete.

Variations of a similar kind, though greater in degree, are presented by *Pentacrinus alternicirrus*. Some individuals have prominent, rhomboidal basals not meeting laterally, like those of *Pentacrinus asterius* (Pl. XIII. fig. 1); while in others they are much less

[1] *Journ. Linn. Soc. Lond.* (Zool.), vol. xv. p. 210; and *Bull. Mus. Comp. Zoöl.*, vol. x., No. 4, p. 168.

prominent and triangular or pentagonal in shape (Pl. XXV.). The same difference appears in *Pentacrinus mülleri*. The specimens in the Copenhagen Museum, one of which is figured by Lütken,[1] have a closed ring of pentagonal basals. Some of those dredged by the "Blake" are in the same condition; but this is far from being the case in the three individuals figured in Pl. XIV. and in Pl. XV. figs. 1, 2. Sir Rawson Rawson's specimen (Pl. XV. fig. 1) has the smallest basals that I have yet seen in this species; while I have met with all intermediate stages between this condition and that of Oersted's types at Copenhagen.

There is also a certain amount of variation in *Pentacrinus blakei*, though I have not seen a sufficient number of specimens to be able to say much about it. In *Pentacrinus naresianus*, again, some individuals have pentagonal basals forming a closed ring; while in others the basals are triangular and barely meet their fellows. But as a rule their outer ends are comparatively small and separated by the radials, which are sometimes prolonged slightly downwards over the upper stem-joints (Pl. XXVIII. fig. 1; Pl. XXX. fig. 1). A few specimens exhibit both conditions, some of the basals meeting their fellows, while the rest are separated by the downward projecting radials.

But the most remarkable variations in the development of the pieces of the basal ring occur in *Pentacrinus decorus*. They are sometimes smaller than those of *Pentacrinus asterius*, and scarcely more conspicuous than the interradial ridges on the stem beneath them (Pl. XXXIV. figs. 1, 8; Pl. XXXV.; Pl. XXXVI. fig. 3); or they may be larger rhomboidal knobs standing out prominently from the general plane of the calyx, and meeting one another by their extended lower angles (Pl. XXXVI. fig. 1; Pl. XXXVII. figs. 1, 2); or they may present any intermediate condition between these two. To some extent these differences are perhaps due to age, both the individuals figured on Pl. XXXV. being very young. But those represented in Pl. XXXVI. are apparently of about the same age, so far as can be judged from the characters of the stem, while their basals are at the two extreme stages of development; and the original of Pl. XXXIV. fig. 1 is very far from being a young individual. In the young *Pentacrinus wyville-thomsoni*, again, the basals are of about the same relative size as they are in the adult (Pl. XVIII. figs. 1–3). I do not, therefore, see any reason for regarding the variations in the development of the basals as of any more importance than the differences in the number of arm-divisions. In *Actinometra parvicirra* the number of arms may vary from thirteen to thirty-nine, and much the same is the case in some species of *Pentacrinus* and *Metacrinus*. But these differences are rarely of specific, and much less of generic value; and in the same way I find it impossible to consider the presence of a closed basal ring as a valid generic character separating *Cainocrinus* from *Pentacrinus*. There is no recent *Pentacrinus* in which the basals do not appear upon the exterior of the calyx, so as to separate the radials either wholly or partially from the

[1] Om Vestindiens Pentacriner, *loc. cit.*, Tab. iv., v., figs. 1, 2.

top stem-joint. A few fossil species, however, have been figured or described as not possessing any external basals. Two of these are from British rocks, *Pentacrinus fisheri* and *Pentacrinus dixoni*. The former was described by Baily,[1] who was unable to detect the presence of interradial basals, and was led therefore to regard the first radials as basals. True basals are really present, however, and may be seen in the original specimen in the Dorchester Museum, or in another found subsequently and now in the possession of Mr. Damon of Weymouth.

The same is the case with the specimen of *Pentacrinus dixoni* in Mr. Willett's collection at Brighton, which was figured in Dixon's Geology of Sussex (1878 edition, pl. xix. fig. 22). In both these species, therefore, the supposed absence of basals is really due to error; and I think it likely that the same may be true both of *Isocrinus pendulus*, von Meyer, and of the Forest Marble specimen from Farley in Wiltshire, which was described by Goldfuss[2] as *Pentacrinus scalaris;* and also of *Pentacrinus pentagonalis personatus* from the Brown Jura. According to Quenstedt[3] three pieces rest on the top of the stem "womit jedes der 5 Hauptradiale beginnt." But neither then nor in the Encriniden did he make any comment on the absence of basals, though he must have noticed it. They may perhaps be small and only just in contact by their central ends, so that they are concealed beneath the radials, as sometimes happens in *Encrinus* and in the fossil Comatulæ.[4] But it appears to me improbable that the embryonic basals of any *Pentacrinus* should have undergone transformation into a rosette, as those of many Comatulæ do. A Stalked Crinoid with a rosette would be a novelty indeed.

One would greatly like to know the real condition of the anomalous specimen of *Metacrinus costatus* represented in Pl. XLIX. fig. 2, which has no basals visible externally. They are generally so very well developed in this genus that their absence altogether seems unlikely; and I suspect therefore that they are quite small and concealed between the top stem-joint and the radial pentagon, as in the case of *Encrinus* and the fossil Comatulæ.

It is a curious fact that there are so very few species of Pentacrinidæ with only one ray-division, *i.e.*, with only ten arms; while at the same time the number of arms rarely reaches the large total of one hundred or more, as it does in some of the giant species of *Actinometra* from the Philippines. In *Pentacrinus maclearanus* (Pl. XVI.), *Pentacrinus wyville-thomsoni* (Pls. XVIII., XIX.), *Pentacrinus alternicirrus* (Pl. XXV.), *Pentacrinus blakei* (Pl. XXXI.), and *Pentacrinus decorus* (Pls. XXXIV.–XXXVII.), the rays may divide three times, *i.e.*, there may be distichal and palmar axillaries above the radials.

[1] Description of a new Pentacrinite from the Kimmeridge, *cf.* Oxford Clay of Weymouth, Dorsetshire, *Ann. and Mag. Nat. Hist.*, ser. 3, vol. vi. pp. 25–28, pl. i.

[2] Petrefacta Germaniæ, vol. i. pl. lx. fig. 10.

[3] Der Jura, 1858, pp. 363, 364.

[4] *Journ. Linn. Soc. Lond.* (Zool.), vol. xv. p. 195, pl. ix. fig. 6.

This would give the maximum number of arms as forty; but although the ten distichal axillaries may all be present, the palmar axillaries are frequently only developed on the two outermost of every set of four secondary arms, as in the unique specimen of *Pentacrinus maclearanus* (Pl. XVI.), and the individual of *Pentacrinus alternicirrus* shown in Pl. XXV. This would give six arms on each ray, making thirty in all. Sometimes, however, there are no palmars at all, or only one or two series of them (Pl. XVIII. fig. 2; Pl. XIX. figs. 1, 6, 7), so that the number of arms varies between twenty and thirty.

The ray-divisions of *Pentacrinus decorus* present almost as much variation as the basals do. Some young specimens have only one or two distichal series (Pl. XXXV.); while one individual has but ten arms like *Pentacrinus naresianus*. In others, again, the arms are more numerous, though palmars are rare (Pl. XXXVI. fig. 1). I am inclined to suspect, from an examination of several young specimens, that the many-armed condition is to some extent a secondary one. Thus if none of the arms were broken and subsequently repaired, the original of Pl. XXXV. fig. 1 would have grown up with no more than eleven arms. When, however, an arm is broken off at a syzygy, and a new one developed in its place, an axillary is nearly always formed in this new one sooner or later, whether there were one present on the original arm or not. An instance of this kind is shown in Pl. XXXVI. fig. 2; and it is not uncommon to meet with individuals of ten-armed species of *Comatula* which have replaced some of their arms after fracture and have developed axillaries in the reparation, so that the number of arms may reach eleven or twelve. This increase in the number of arms after reparation seems to take place largely in *Pentacrinus decorus*; for it is rare to meet with a specimen which does not show these signs of reparation, certain axillaries and the arms which they bear being distinctly smaller than their fellows.

In *Pentacrinus asterius* and *Pentacrinus müllleri* there are always twenty arms or more, all the primary arms ending in distichal axillaries. Most of the secondary arms bear palmar axillaries, and there are sometimes even one or two more beyond these, so that the rays may divide five times in all. There is no special regularity of division in *Pentacrinus asterius*, though the number of arms is large, exceeding one hundred, according to Sir Wyville Thomson.[1] But in *Pentacrinus müllleri* there are usually not more than four ray-divisions, the (palmar) axillaries being limited to the outer arms as in *Pentacrinus maclearanus* and *Pentacrinus alternicirrus*; while the fourth and fifth axillaries, if present, occupy a similar position, so that there are six, eight, or ten arms to the ray, as 2, 1; 1, 2—2, 1, 1; 1, 1, 2—or 2, 1, 1, 1; 1, 1, 1, 2.

The arms of *Metacrinus* branch as a rule more freely than those of *Pentacrinus*, except *Pentacrinus asterius*, all of the species having two, and most of them four axillaries beyond the radials; but there is no special regularity about the grouping of the arm-divisions.

[1] Sea Lilies, *The Intellectual Observer*, August 1864, p. 5.

Among the recent Pentacrinidæ there is but one solitary example of a uniformly ten-armed type, which embraces a majority of the species of *Antedon*. This is *Pentacrinus naresianus*, represented in Pls. XXVIII.–XXX.

Owing to the fragmentary condition in which many of the fossil Pentacrinidæ occur, it is impossible to say much about the nature of their arm-divisions. But in *Pentacrinus beaugrandi*, de Loriol,[1] sp., the remains of the primary arms bear no axillaries up to the twelfth joint from the radials; while eleven simple joints are still preserved in the specimen from the Lias of Vaihingen, which is referred by Quenstedt to *Pentacrinus tuberculatus*.[2]

Reference has already been made to the low state of development of the arms of recent Pentacrinidæ as compared with those of Comatulæ (*ante*, p. 55). They are fewer in number (*i.e.*, when multiradiate forms are compared), and have both pinnules and ambulacral plating less developed towards their ends; while the number of joints separating successive axillaries is far more variable within specific limits, and does not seem to have become tolerably fixed as is the case in the Comatulæ. Singularly enough, the two species *Pentacrinus wyville-thomsoni* and *Pentacrinus alternicirrus*, in which the distichal and palmar series are most uniform, are the very ones which most resemble the Comatulæ in their mode of life (*ante*, p. 19).

It is curious that in the Pentacrinidæ and Apiocrinidæ the external appearance of the arm-joints should be so much more constant than it is among the Comatulæ. In the latter family the arm-joints may be saucer-shaped, more or less sharply wedge-shaped, &c., and it is in many cases easy to identify a species from detached portions of the arms, especially as there is also very considerable variation in the characters of the pinnules. But both in *Pentacrinus* and in *Metacrinus* there is a very great sameness, not only in the form of the arm-joints as seen from their dorsal side, but also in the appearance of the pinnules which they bear. The tubercular projections on the pinnule-joints of *Pentacrinus asterius* (Pl. XIII. figs. 1, 14), and the indications of carination on the pinnules of a few species of *Metacrinus*, are almost the only variations in the character of the pinnules through all the recent species of the family. It is true that the features of the lower pinnules of *Metacrinus* are such as to afford a character of some generic value for separating it from *Pentacrinus*. But with the exceptions above mentioned the pinnules of all the different species of *Metacrinus* are very much alike. Both in this genus and in *Pentacrinus* the arm-joints are almost invariably of the transversely oblong type (Pls. XI., XIV.; Pl. XV. figs. 2, 3; Pl. XVI.; Pl. XVIII. figs. 1–3; Pl. XIX. figs. 1, 6, 7; Pls. XXV., XXXVI., XXXVIII., XLII., XLIII.–XLVI., XLVIII., XLIX., LII.); and the same is the case in most, if not all, of the fossil species. It is therefore at first sight by no means easy to identify the species to which isolated

[1] Monographie des Étages Jurassiques Supérieurs de Boulogne-sur-Mer, 2me partie, p. 298, pl. xxxvi. fig. 23, *a*.

[2] Encriniden, Tab. 97, fig. 39.

arm-fragments belong. But as I have pointed out above, the peculiarities of the arm-grooves upon the ventral surface of the skeleton, and their relation to the ambulacra, afford characters of considerable systematic value. The joints of *Pentacrinus naresianus*, however (Pls. XXVIII., XXIX.; Pl. XXX. figs. 1, 23), show a distinct indication of the more oblique shape which is common among the Comatulæ; while both in this species and in *Pentacrinus blakei* the peculiar nature of the syzygial union renders the arms very readily distinguishable (Pl. XXX. fig. 23; Pl. XXXa. figs. 9–12; Pl. XXXI. figs. 1, 2; Pl. XXXII. figs. 5, 7, 12, 14).

The characters of the stem of the Pentacrinidæ have already been fully discussed (*ante*, pp. 12–23). The fact that during growth it undergoes rather considerable modifications in its appearance has led to a very general belief in the impossibility of identifying species by means of stem-fragments only. This is more especially the case as regards the fossil species, which are often based upon the stem-characters alone, since calyces are but rarely met with; and I think it not improbable that two or even more types of stem from the same horizon, to which different specific names have been given, may sometimes be only different stages of growth of one and the same species. Thus, for example, four species might be made out of the joints represented in Pl. XXII. figs. 13, 14, 23, and 26, which are, however, merely different stages of growth in the stem of *Pentacrinus wyville-thomsoni*. But on the other hand, the difference between the stem-fragments figured on Pl. XIII. fig. 8 (*Pentacrinus asterius*) and Pl. XIX. fig. 4 (*Pentacrinus wyville-thomsoni*) are obviously not due to any developmental causes; and the two would be universally recognised as belonging to different species, even if nothing whatever were known about the calyces and arms belonging to them. The same remark holds good in the case of *Metacrinus*, isolated stem-fragments of *Metacrinus alternatus* (Pl. XXXIX. fig. 3), *Metacrinus cingulatus* (Pl. XLI. fig. 1), and *Metacrinus nobilis* (Pl. XLI. fig. 5), to say nothing of other species, being very readily recognisable.

What has been written above refers simply to the general appearance of the stem-fragments; but when the number of internodal joints is taken into consideration, and also the markings on their terminal faces, the characters of the stem as a whole must be regarded as of very considerable systematic value. The stem-joints of *Balanocrinus* and *Extracrinus* are very readily identified by the sculpture on their faces; but as far as the internodal joints are concerned, I am unable to find any constant difference in this respect between *Pentacrinus* and *Metacrinus*. In most (recent) species of both genera there are from three to six strongly marked ridges along the sides of each petaloid figure. The proximal ridges join their fellows in each interpetaloid space, while the outer ones reach the exterior and cause the crenulation along the line of union between every two joints, the ridges of each face alternating in position with those of the face opposite to it (Pl. XIII. figs. 10, 11; Pl. XXII. figs. 22–24; Pl. XXVI. fig. 17; Pl. XXX. figs. 25–30;

Pl. XXXVI.; Pl. XXXVII. fig. 22; Pl. XXXIX. figs. 4, 7–11; Pl. XLI. figs. 1–3, 5–8, 15–17; Pl. XLV. figs. 2, 4; Pl. XLVII. figs. 1–9; Pl. XLIX. figs. 3–5).

The same characters may be seen in the numerous *Pentacrinus* joints figured in Tabs. 97–99 of the Encriniden, and on pls. xiv.–xvii. of de Loriol's Swiss Crinoids. In some of these fossil joints the number of ridges at the sides of the petaloid figures may sometimes reach eight or ten; but the inner ones always meet their fellows in the interpetaloid spaces, while the outer ones appear externally. This is not the case in *Extracrinus*, which has a more extensive but smaller crenulation at the sides of the linear petals, as pointed out already (*ante*, p. 276).

In the recent species of *Pentacrinus* the cirrus-socket may extend downwards below the articular surface so as to encroach very considerably on the internodal joint beneath it, as in *Pentacrinus naresianus* and *Pentacrinus decorus* (Pl. XXXa. fig. 6; Pl. XXXVI.), and in a less degree also in *Pentacrinus mülleri* and *Pentacrinus blakei* (Pl. XXXI. fig. 3); or the joint above the node may be slightly incised to receive the upper part of the socket, as in *Pentacrinus alternicirrus* (Pl. XXVII. fig. 1), *Pentacrinus wyville-thomsoni* (Pl. XIX. figs. 3, 4), and occasionally also in *Pentacrinus asterius*. But in these cases the alteration of the supra-nodal joint is not very considerable. Among the *Pentacrinus* species it is most marked in *Pentacrinus wyville-thomsoni* (Pl. XXII. fig. 17). With the exception of those on the lowest nodal joint the cirri of this type are often found directed upwards (Pl. XIX. fig. 1), while in others like *Pentacrinus mülleri*, *Pentacrinus maclearanus*, *Pentacrinus naresianus*, *Pentacrinus blakei*, and *Pentacrinus decorus* they are directed downwards (Pls. XIV., XVI., XXVIII., XXIX., XXXI., XXXIV.), and their bases are received in the hollowed sides of the infra-nodal joints.

On the other hand, the tendency of the cirri of *Metacrinus* is to take an upward direction, the supra-nodal joints being slightly incised to receive their bases. This is well shown in *Metacrinus angulatus* (Pl. XXXVIII.; Pl. XXXIX. fig. 9), *Metacrinus cingulatus* (Pl. XL.), *Metacrinus wyvillii* (Pl. XLVIII.), *Metacrinus costatus* (Pl. XLIX. figs. 1–3), *Metacrinus interruptus* (Pl. LII.), and *Metacrinus tuberosus* (Pl. LIII. figs. 1, 2). In some species, such as *Metacrinus varians* (Pl. XLIV.), this character is not very prominent; but it can be traced with more or less distinctness in all the species of the genus that I have seen, and is therefore (as far as it goes) of considerable value in the separation of *Metacrinus* from *Pentacrinus*, as in the case of *Metacrinus tuberosus* (Pl. LIII. figs. 1–6) and *Metacrinus stewarti*,[1] of which only the stems are known. But I have been unable to apply it to the determination of any fossil species, as this point is naturally but rarely illustrated in sufficient detail in the figures of Quenstedt and de Loriol.

[1] On Three New Species of Metacrinus, *Trans. Linn. Soc. Lond.* (Zool.), ser. 2, vol. ii. p. 443.

B. *On the Characters of Young Pentacrinidæ.*

Young individuals of *Pentacrinus* are naturally rare, as is only to be expected. It is related, however, that on one occasion a large number of them of all ages and sizes were thrown up on the shore at Barbados after a gale; but unfortunately for science no one on the spot had knowledge enough to recognise the value of this extraordinary event, and a great opportunity, such as may never occur again, was therefore lost.

Nevertheless the discovery that recent Pentacrinidæ flourish in great numbers on certain parts of the sea-bed, like their predecessors in the Liassic and Jurassic Seas, has brought about a considerable increase in our knowledge of their premature stages of growth. The dredgings of the "Porcupine," Challenger, and "Blake" have yielded several young individuals of three *Pentacrinus* species and of *Metacrinus nodosus*, some of which are figured on Pls. XVIII., XXXa., XXXV., and LI.

Like the young *Comatula*, they are all distinguished by the relatively great height of the first radials as compared with those of the adult, which are wider than high, often considerably so (Pl. XIX. figs. 1, 6, 7; Pl. XXX. fig. 1; Pl. XXXVII. figs. 1, 2; Pl. L. figs. 1, 5), while the radials of the young individuals are spade-like, to use an expressive term introduced by Sir Wyville Thomson. This is naturally most marked in the youngest specimen with a total length of 80 mm. (compare Pls. XXXV. and XXXVII.); and the cup with its small basals presents a singular resemblance to that of *Plicatocrinus* and *Bathycrinus* (Pl. VII. figs. 1–3, 6; Pl. VIIIa. fig. 1). The little we know of the former, however, shows that it is a totally aberrant type, and the resemblance must therefore be considered as in great measure accidental and not as indicating any genetic relationship. But *Bathycrinus* is a decidedly embryonic form, as is shown by the length of all its three radials and the absence of pinnules from the arm-bases. *Hyocrinus* (Pl. VI.) is another type with high spade-like radials; but the basals are of the same character, and not small and inconspicuous as in young Pentacrinidæ and in *Bathycrinus*, while the arms are totally different.

Another character of the incompletely developed Crinoid, which is very marked in *Rhizocrinus* and *Bathycrinus*, and still more so in the aberrant *Plicatocrinus* and *Hyocrinus*, is the comparative freedom of the second radials. In many Comatulæ they are closely united laterally; while in most of the Palæocrinoids, as in *Apiocrinus* and *Guettardicrinus*, they are practically immovable, and enter into the composition of the body. The second radials of *Pentacrinus*, however, rarely show any traces of the lateral pits lodging interradial ligaments such as occur in many multiradiate Comatulæ. But they are often in very close apposition, while in young individuals of the same species they are comparatively free (Pls. XVIII., XIX., XXIX., XXXa., XXXV., XXXVII.). The arm-joints of most young Crinoids, as well as those in the outermost and growing parts of the arms of more mature individuals, are always distinguished by

the relatively great proportion of length to width, whatever may be the shape of the full-grown joint. In some Comatulæ this condition is permanently retained, but in others and in the Pentacrinidæ the arm-joints of mature individuals are usually much wider than long. In accordance with this, we find that even in young individuals of *Pentacrinus decorus* with quite high radials and arms only 12 mm. long, consisting of about a dozen properly formed joints, the great relative width of the latter is already very distinctly indicated (Pl. XXXV.); while the last few joints are much smaller than their predecessors, and have rather the appearance of a pinnule than of the continuation of the arm, the preceding joint of which looks like an axillary bearing two small arm-stumps.

This mode of development is less marked in a somewhat older individual of *Pentacrinus decorus* with about forty arm-joints, the later ones of which gradually decrease in size instead of becoming abruptly smaller; and the imperfect state of development of the later pinnules which is so characteristic of the Pentacrinidæ is very well shown. This would seem to indicate that the mode of growth of the arm-bases proceeds on a different plan from that of their middle and outer portions. In still larger individuals, as in the youngest specimens of *Pentacrinus wyville-thomsoni* (Pl. XVIII. fig. 3), *Pentacrinus naresianus*[1] (Pl. XXXa. fig. 1), and *Metacrinus nodosus* (Pl. LI. fig. 1), the terminal arm-joints are distinctly longer than wide, although the lower ones have almost assumed their adult form; and in all of them, but especially in *Metacrinus nodosus*, there is the characteristic reduction in the size of the later pinnule . . . to be learnt regarding the order of the pinnule-succession in the Pentacrinida . . . these young individuals; for the smallest of them are larger than some young . . . already detached from the stem, but without pinnules on the arm-bases, and they all have their proper complement of pinnules. The stem-joints of the immature Pentacrinidæ, like the later joints of growing arms, are relatively high in proportion to their width. This is exactly the reverse condition to that of the young joints formed immediately beneath the calyx (Pl. XXXIV. fig. 9). The same distinction appears in the very different type of stem characteristic of the *Comatula*-larva and of the Bourgueticrinidæ (Pl. VII. fig. 11; Pl. VIIIa. fig. 1; Pl. LIII. figs. 7, 8). The young joints are at first discoidal, then lengthen out, and finally the width increases relatively to the length so as sometimes even to exceed it considerably. The two types of stem are so very different that it is perhaps a little rash to reason about the one on the basis of the other. The intercalation of new joints, which is so characteristic of the Pentacrinidæ, seems never to occur in the Bourgueticrinidæ, new joints being only formed beneath the calyx. In this last respect, however, the mode of growth in the youngest Pentacrinidæ with very slender stems appears to be very much what it is in the equally slender *Rhizocrinus* and *Bathycrinus*. But as the diameter of the stem increases to 3 or 4 millimetres the

[1] The arm-joints of this species are more like those of the Comatulæ than is the case in any other *Pentacrinus*. Instead of being nearly oblong, they have somewhat oblique ends, especially in the lower parts of the arms (Pls. XXVIII.–XXX.).

length of the joints does not increase in the same proportion; and I am therefore not surprised at having met with but one individual in which the stem-joints are longer than wide, as shown in Pl. XXXV. fig. 1.

A comparison of the figures on this plate, which represent the two youngest individuals dredged by the "Blake," with those of the older, but still immature forms figured in Pl. XXXVI., will show, however, that the great relative height of the stem-joints is a very characteristic feature in the development of *Pentacrinus decorus*. The same feature is apparent in *Pentacrinus wyville-thomsoni* (Pls. XVIII., XIX.), *Pentacrinus naresianus* (Pl. XXVIII.; Pl. XXXa, fig. 1), and *Metacrinus nodosus* (Pl. L. fig. 3; Pl LI. fig. 1).

The sculpture on the terminal faces of these internodal joints of young individuals (Pl. XXXa. figs. 2, 3; Pl. XXXVII. fig. 9; Pl. LI. figs. 2–5), as in the case of those intercalated between the pre-existing joints in other stems (Pl. XXII. figs. 3–12; Pl. XXXVII. figs. 10, 13, 14), is more or less obscure; but the petaloid markings are evident from the first, as might be expected.

The external appearance of the nodal joints not unfrequently alters considerably during growth. Thus, for example, in *Pentacrinus decorus* the characteristic expansion down to the upper edge of the cirrus-socket (Pl. XXXVI.) scarcely appears at all in the young nodal joint (Pl. XXXVII. fig. 5); while in *Pentacrinus naresianus* there is a trace of this expansion in the young stem, though it entirely disappears in the adult. In *Pentacrinus wyville-thomsoni*, again, the overlap of the lower edge of the cirrus-socket above the infra-nodal joint is far less evident in the young stem (Pl. XVIII. fig. 3) than it is in the adult (Pl. XIX. figs. 3, 4). In *Metacrinus nodosus*, however, the characteristic enlargement of the nodal joints between their cirrus-sockets is very evident in a young stem with relatively high joints (Pl. LI. figs. 6, 7).

C. *The Calyx and its Contents.*

The calyx, *i.e.*, the combined ring of basals and radials, is constituted in the same way in both the living genera of Pentacrinidæ, viz., *Pentacrinus* and *Metacrinus*, as is evident from a glance at Pl. XII. The former may therefore be taken as the type; for it is the better known genus, and has a long geological history, while *Metacrinus* is not yet known to occur in the fossil state. The calyx of *Pentacrinus*, while more like that of ordinary Comatulæ, *i.e.*, *Antedon*, *Actinometra*, and *Eudiocrinus*, than the corresponding part is in *Rhizocrinus* and *Bathycrinus*, nevertheless differs from it in a very important character. This is the presence of unmetamorphosed basals, such as are only found in *Atelecrinus* and *Thaumatocrinus* (Pl. LVI. figs. 1–4) among Comatulæ; for the embryonic basals of the ordinary types undergo the well known transformation into a rosette. This structure covers in the chambered organ which is lodged within the

cavity of the centro-dorsal (Pl. LXI. fig. 2), and the same is the case with the flattened basals of *Atelecrinus*.

The chambered organ of *Pentacrinus* is both relatively and absolutely smaller than that of *Comatula*, and the reason for this is obvious. The Comatulid centro-dorsal represents, as it were, a coalesced series of the nodal stem-joints of *Pentacrinus*, and the five cavities of the chambered organ lodged in its upper part are each in connection with one cirrus-vessel only. But the remaining cirri which are borne by the centro-dorsal in greater or less abundance are supplied by a number of vessels that come off below the chambers. Within the dorsal portion of the chambered organ, "lying at the bottom of the centro-dorsal basin, there is a succession of verticils of five triangular leaflets, increasing in size from below upwards, from the extremities of some of the upper of which leaflets issue groups of three diverging cords that proceed to the cirri. I can scarcely doubt that these verticils mark the origins of the earlier cirral cords from the Crinoidal axis; and this obviously suggests that the five-chambered organ is itself only another and larger verticil, which has come by the formation of ventricular cavities in its substance (analogous to the lateral ventricles of the brain), to occupy the whole cavity of the enlarged centro-dorsal basin."[1] In *Pentacrinus*, however, the cirri all come off from the nodal joints of the stem, where the five downward prolongations of the cavities of the chambered organ in the calyx enlarge and each gives off a cirrus-vessel (Pl. XXIV. figs. 3, 4, *chn*). No cirrus-vessels come off from the enlargement of the vascular axis within the calyx, which represents the chambered organ of *Comatula* without the verticils of cirrus-vessels below it. The chambers, however (Pl. XXIV. figs. 6–8, *ch*), are scarcely larger than the nodal cavities in the stem from which the cirrus-vessels arise,[2] and are much smaller than the corresponding chambers within the upper part of the centro-dorsal of *Comatula* (Pl. LXI. fig. 2), which give off the vessels to the younger cirri. In fact they are sometimes almost equalled in size by the central vessels within the ring of chambers, as seen in Pl. XXIV. fig. 6. They are not closed below as is practically the case in the Comatulæ, nor do they present as sudden enlargements of the stem-vessels as in *Rhizocrinus* and *Bathycrinus;* but these vessels are, as it were, permanently enlarged in the upper part of the stem, owing to the closeness of the nodal joints which are successively formed beneath the calyx, and are only gradually separated by the intercalation of internodal joints between them. The chambers of *Pentacrinus* therefore taper very gradually downwards into the stem-vessels, and it is difficult to say where the latter begin and the former end (Pl. LVIII. fig. 3).

The primary Y-shaped interradial cords which come off from the fibrillar envelope surrounding the chambered organ of *Pentacrinus* (Pl. XXIV. fig. 7; Pl. LVIII. figs. 1, 3—*a.i.*) sometimes bifurcate before entering the basals. On the inner face of the

[1] See W. B. Carpenter, *Proc. Roy. Soc.*, vol. xxiv., 1876, p. 219.

[2] Compare Pl. XXIV. figs. 3, 4, 6, which are all equally magnified.

basals of *Pentacrinus decorus* there is but one central opening, so that the primary cords fork within the basals (Pl. LVIII. fig. 1) as they did in *Apiocrinus*. But in *Pentacrinus blakei* this opening is widely extended laterally, while in *Pentacrinus naresianus*, *Pentacrinus alternicirrus*,[1] and especially in *Pentacrinus wyville-thomsoni* (Pl. XXI. fig. 7*a*), it is more or less completely divided into two by a vertical partition. In *Pentacrinus asterius* and *Metacrinus angulatus*, both of which, and especially the latter, have large basals with a great development of calcareous network on the upper ends of their inner faces, the opening of the central canal is pretty distinctly double.

On the upper surface of the basals the openings are, of course, perfectly separate. They are situated on either side of the median ridge, and correspond to similar openings on the under surface of the two contiguous radials which partly rest upon each single basal (Pl. XII. figs. 11, 14, 22, 25; Pl. XVIII. figs. 5, 7; Pl. XX. figs. 2, 3, 6, 9; Pl. XXI. figs. 6, *a*, *b*, *c*, and 7, *b*; Pl. XXVI. fig. 9; Pl. XXX. figs. 5, 7, 8; Pl. XXXIII. fig. 5; Pl. L. fig. 5). In most specimens of *Pentacrinus wyville-thomsoni*, as in other Pentacrinidæ, removal of the basals exposes the apertures on the lower surface of the radials where the secondary axial cords enter them, together with the lowest portion of the central plug (Pl. XX. fig. 9). But in one individual of *Pentacrinus wyville-thomsoni* Dr. Carpenter found this plug to be somewhat unusually developed. Its lower surface forms a tolerably well defined pentagonal plate, the angles of which are interradial in position (Pl. XX. figs. 4, 5, 6, 8). It lies between the basals and radials, and is pierced in the centre for the passage of the plexiform gland rising out of the chambered organ, together with openings through which the secondary axial cords passed on their way from the basals to the radials, the apertures in the latter plates being entirely concealed by it.

The radials of *Pentacrinus* thus differ very considerably from those of *Comatula*, for the proximal openings of their central canals are really on their dorsal faces, viz., at the central ends of what I have called the inner dorsal surface, *i.e.*, that part which rests on the basals (Pl. XII. figs. 11, 22; Pl. XX. fig. 9; Pl. XXI. figs. 6*a*, 6*b*, 6*c*; Pl. L. fig. 5); whereas in the Comatulæ, as I have shown elsewhere,[2] these openings are on the inner faces of the radials, *i.e.*, those which form the walls of the radial funnel that contains the plexiform gland rising from the chambered organ. They are also less closely approximated in *Pentacrinus* than in *Comatula*, one being situated on either side of the strong crest which divides the inner dorsal surface into two lateral halves, instead of being only separated by a very delicate calcareous bar. The converging axial cords which enter these openings on the radials of *Pentacrinus* (Pl. XXIV. figs. 7–9; Pl. LVIII. figs. 1–3—*ar*) run upwards and outwards for some little way before they are united by the interradial and intraradial cords to form the circular commissure

[1] I have only seen single specimens of the dissected calyx in these three species.

[2] *Trans. Linn. Soc. Lond.* (Zool.), ser. 2, vol. ii. p. 78, pls. iv.–vii., 1877.

(Pl. XXIV. fig. 9, *ico*, *cco*). The canal in which this is lodged is never close down to the proximal openings in the inner or dorsal face, as it is in all Comatulæ, even *Atelecrinus*. But its position varies somewhat in different species. Thus, for example, it comes nearer to the edge of the central funnel in *Pentacrinus decorus* (Pl. XXXIII. fig. 5) than in *Pentacrinus wyville-thomsoni* (Pl. XX. fig. 6). The double axial cords of the rays which proceed outwards from it resemble those of Comatulæ in their very close approximation. Small portions of them, cut very obliquely, are seen in Pl. XXIV. fig. 9, A. They are lodged close together in the same canal as far as the axillary radial, not being so widely separated as in *Encrinus;* and the arrangement of the commissures in the axillary is just the same as was discovered by Ludwig in the Comatulæ.

D. *The Geological History of Pentacrinus.*

Excepting for some doubtful forms from the Eifel, the earliest known Pentacrinidæ occur in the "Wellenkalk" of the Jura, at an horizon somewhat lower than the well-known limestone in which *Encrinus liliiformis* occurs. According to Quenstedt, both generic types occur together in the Wellenkalk of Würtemberg; and he refers all the Pentacrinidæ to one species, *Pentacrinus dubius*, though they have received various other names, both generic and specific, from earlier writers. Nothing being known of them but fragments and isolated joints of the stem, any detailed classification of them is hardly possible. But the similarity of the stem-fragment from Waltershausen[1] with ten cirrus-whorls at intervals of eight or ten joints, to the stems of recent Pentacrinidæ, is very striking. This resemblance was noticed by von Schlotheim,[2] who described the fossil as *Pentacrinus vulgaris*, and referred to the same type the recent specimens of Guettard and Ellis. Some years later Quenstedt[3] gave an excellent figure of it; but in the absence of an associated calyx he hesitated to refer it to *Pentacrinus* as von Schlotheim and Goldfuss had done, and so described it as *Encrinites dubius*. Beyrich and later writers, however, have generally regarded it as a *Pentacrinus*, as Quenstedt himself has done in the Encriniden, and the reference of the fossil to the Pentacrinidæ will now be scarcely disputed. Another very similar stem from the Muschelkalk of Silesia was described by von Meyer[4] as *Chelocrinus acutangulus*. This genus was established to receive certain forms with more than ten arms, owing to the presence of distichal and palmar series, which had been generally referred to *Encrinus*. It has been abundantly proved, however, by the researches of von Strombeck[5] and others,

[1] Encriniden, p. 198, Tab. 97, figs. 14–22.

[2] Die Petrefactenkunde, p. 327.

[3] Ueber die Encriniten des Muschelkalks, *Archiv f. Naturgesch.*, Jahrg. i. Bd. ii., 1835, p. 225, Taf. iv. fig. 2.

[4] Fische, Crustaceen, Echinodermen und andere Versteinerungen aus dem Muschelkalk Oberschlesiens, Palæontographica, Bd. i., 1851, p. 272.

[5] Ueber Missbildungen von Encrinus liliiformis, Lam., Palæontographica, Bd. iv., 1856, p. 176.

that the character on which von Meyer established *Chelocrinus* is one of no systematic value whatever. One of the two species on which he founded the genus was the *Encrinus pentactinus* of Bronn.[1] This name was proposed for a single specimen which presented a very remarkable combination of characters. The cup appears to be that of a typical *Encrinus* with some twenty biserial arms. The stem has a rounded pentagonal outline, and consists of about twenty-five joints, some of which bear verticils of five cirri. Beyrich appears to consider these characters as of altogether subordinate value, for he says[2]—"die etwas abweichende Form des fünfseitigen Stengels mit deutlich eingesenkten Seiten kann eben so wenig für ein unterscheidendes Artmerkmal gelten, wie die von Bronn beobachteten kurzen Cirren, welche anscheinend individuell hier und da bei verschiedenen *Encrinus*-arten vorkommen können." There is a considerable difference, however, between a regular verticillate arrangement of cirri and their occasional presence here and there upon the stem, about which Beyrich does not speak very confidently, so far as *Encrinus* is concerned. I cannot make out, indeed, that any stem of an *Encrinus* has ever been described as bearing isolated cirri in the manner referred to by Beyrich; while, on the other hand, the verticillate arrangement has been discovered by Picard[3] in an imperfectly preserved fragment from the Muschelkalk which he has described as *Encrinus beyrichi*—"Der Stengel ist von seinem untersten Theile an mit Ranken versehen. Dieselben treten von unten herauf erst spärlicher und in grösseren Abständen auf; am oberen Theile ist je das achte Säulenglied ein Cirrenträger und erscheint horizontal etwas verdickt. Die Anhaftestelle für die Cirre befindet sich regelmässig auf der concaven Fläche zwischen je zwei der fünf Kanten, so dass ein Wirtel von 5 Cirren den Stiel umgiebt." He continues—"Als *Pentacrinus* wage ich meinen Fund nicht auszusprechen. Denn obwohl die Fülle an Cirren und der ganze Habitus der Säule sehr zu dieser Auffassung drängt, hat mich doch die Zusammensetzung der Krone, soweit sie klar ist, bestimmt, bei der Gattung *Encrinus* zu bleiben." There would seem therefore to be no doubt as to the occurrence of cirrus-verticils on the stems of other Neocrinoids besides the Pentacrinidæ; while there are certain Palæocrinoids both in this country and in America which present the same character. Although, however, this fact diminishes the value of that peculiarity of the Pentacrinidæ which is most evident at first sight, it does not follow that the verticillate arrangement of the cirri in these other types is also associated with the presence of syzygies at the nodes and the mode of union of the internodal joints, which are such especial features of all the Pentacrinidæ. The *Pentacrinus dubius* of Goldfuss and Quenstedt shows these points very well, the five petals being visible on the faces of many joints found in the Muschelkalk at different localities; while the stem of von Schlotheim's specimen (6 inches long)

[1] Ueber die Krinoideen-Reste im Muschelkalk, *Neues Jahrb. f. Mineralogie*, Jahrg. 1837, p. 32, Taf. ii.
[2] Crinoideen des Muschelkalks, *loc. cit.*, p. 36.
[3] *Zeitschr. d. deutsch. geol. Gesellsch.*, Jahrg. 1883, p. 201.

terminates below in a nodal joint owing to its separation at the syzygy, as is the case with so many fossil as well as recent Pentacrinidæ. Although therefore it seems tolerably certain that cirrus-verticils may occur in some species of *Encrinus*, the other characters of many of the stem-fragments from the Muschelkalk render it equally certain that *Pentacrinus* or an allied genus existed in the same seas as *Encrinus*. This has long been admitted in the case of the St. Cassian beds, which are considerably above the horizon of the Muschelkalk; and they have yielded to Laube[1] five varieties of *Pentacrinus*-stems, which he has temporarily referred to as many species. Associated with these he found one calyx which appears to belong to *Pentacrinus;* but it was too imperfectly preserved for a definite opinion to be formed upon this point.

All these earlier forms seem to belong to the section of the genus which was designated "Basaltiformes" by Quenstedt, after one of Miller's species with a pentagonal stem. Essentially similar stems are found all through the remaining secondary rocks from the Lias upwards, in the Nummulitic Limestones of Biarritz and Kressenberg, in the London Clay, and in the Italian Tertiaries. The calyces associated with them have a monocyclic base, and bear simple or dichotomous arms, the two limbs of each fork being of equal value, just as in the recent forms. Quenstedt's other two groups, the Briariden and the Subangularen, are those to which the generic name *Extracrinus* was applied by the Messrs. Austin. The type is limited in Europe to the Lias and Lower Oolites. *Extracrinus briareus* appears to occur in the lowest "quick ledge" at Lyme Regis, which corresponds to Quenstedt's lowest bed *a*; but the type does not reach into the Middle Lias, nor indeed into the upper beds of the Lower Lias. In the Jura, however, *Extracrinus briareus* has not been found below the Marlstone (Lias γ and δ); but it ranges up through the *Posidonia*-beds, and is said to occur in the Lower Oolites.

The range of the Subangularen is more limited. They do not occur in the Lower Lias of either England or Germany, nor do they reach the top of the *Posidonia*-beds. Many varieties have been made of both species, especially by Quenstedt; but it is noteworthy that neither species occurs in all the three divisions of the Lias, *Extracrinus briareus* being limited to one only, at any rate in this country.

Those who have recognised *Extracrinus* as a genus, as, for example, Mr. R. Etheridge,[2] F.R.S., have usually regarded it as limited to the Lias. The Messrs. Austin, however, speak of *Extracrinus briareus* as occurring in the Cornbrash at Kingscote Turnpike. They are certainly wrong about the species, but I am very strongly inclined to believe that they are correct as regards the genus, and also that the occurrence of the Briariden in the Brown Jura (Inferior Oolite), as mentioned by Quenstedt,[3] is not unlikely.

[1] Die Fauna der Schichten von St. Cassian, *Denkschr. d. k. Akad. d. Wiss. Wien.*, Bd. xx., xxiv., pp. 267–278.

[2] See his Presidential Address to the Geological Society, *Quart. Journ. Geol. Soc.*, 1882, p. 147 (of separate copy).

[3] Encriniden, p. 270.

In the year 1876 a large *Pentacrinus* colony was discovered at Sennecey-le-Grand. Numerous very perfect individuals were obtained and carefully described by de Loriol.[1] He found a verticil of cirri on every joint, and described their faces as follows:—"La surface articulaire est plane; les petales de la rosette articulaire sont fort étroits, et ont l'apparence de cinq petites rigoles aboutissant aux cinq angles du pentagone et limitées par deux petits bourrelets parallèles, plus élevés sur l'une des faces de l'article que sur l'autre, et couverts de très fines crénélures." The figure which he gives (pl. ii. fig. 10) shows the complete correspondence of these joints with those of the Liassic *Extracrinus;* and he found this correspondence also in the other characters of the type. The radials extend slightly downwards over the top stem-joints, and the characters of the arm-divisions are almost exactly as in *Extracrinus*, except that the main arms and the armlets which they bear are more equal in size than in the typical species.

De Loriol identified this species with *Pentacrinus dargniesi* of Terquem and Jourdy, though he considered it as belonging to the same group as *Extracrinus briareus;* but he hesitated to adopt Austin's genus, and he subsequently stated that there was no reason to do so.[2]

He also pointed out that the characters of the stem-joints and cirri of Quenstedt's two species *Pentacrinus briareus zöllerianus* and *Pentacrinus briareus achalmianus*, both from the Brown Jura (Inferior Oolite), indicate their affinity to this group. In the same memoir he described and figured some other stem-joints presenting all the *Extracrinus* characters from the same formation (Bajocien) of Langres, and he subsequently found both these types at corresponding horizons in Switzerland. He referred at the same time to the *Pentacrinus nodotianus*, d'Orbigny, which was described by its founder as being "voisine du *Pentacrinus briareus*." Very similar stem-joints, each bearing five cirri, and having crenulated linear petals, occur in the Coralline Oolite of various parts of Switzerland, and are described as *Pentacrinus buchsgauensis* by de Loriol, who notes their resemblance to those of *Pentacrinus briareus* as a point of special interest.[3]

We may therefore, I think, consider it certain that *Extracrinus* extends up above the Lias into the Lower Jurassic rocks of the Continent, and the same is undoubtedly the case in England. The Great Oolite of Minchinhampton contains stem-joints with the same linear, crenulated petals as those of the Liassic *Extracrinus briareus;* while similar joints, together with arm-fragments showing the characteristic inequality of division, abound in the Forest Marble at Malmesbury.

To the genus *Extracrinus* I would also refer the *Pentacrinus asteriscus* from the

[1] Notice sur le Pentacrinus de Sennecey-le-Grand, p. 7. Both in this work and in the Swiss Crinoids this type is called *Pentacrinus dargniesi* by de Loriol. But the plates are lettered *Pentacrinus chabasi*, P. de Loriol.

[2] Swiss Crinoids, p. 116.

[3] *Ibid.*, pp. 153, 154.

American Jura-Trias (Jura only?), which was first discovered by Meek and Hayden.[1] It was subsequently found in Utah by Wheeler's Survey, and owing to the constancy of its characters, even in examples collected at widely separate localities, it has been relied on with considerable confidence in the identification of Jurassic strata. According to Meek and Hayden there are five large, oval, petaloid areas, bounded on either side by "rather narrow, slightly elevated, transversely crenulated margins,"[2] and the figure which was published later by White[3] clearly shows that the affinities of this species are with *Extracrinus* rather than with *Pentacrinus*, of which it has been hitherto regarded as the only species yet recognised in the American Jurassic rocks. Hayden's Survey found it in 1877 extending through a considerable thickness of Jurassic limestones in Idaho and Wyoming.[4] The supposed Triassic beds of Dun Glen and the Pah Ute range contain a slightly larger form of joint, which differs from the Jurassic specimens. It was found associated with what are regarded as unmistakable Triassic fossils and also a *Spirifera*. Mr. Emmons[5] speaks of it as follows:—"It should be stated also that these disks of *Pentacrinus* found in the Dun Glen limestone vary somewhat from the type specimens, and are all of larger size, reaching one-fourth of an inch in diameter, while those of Jurassic age scarcely reach one-fifth of an inch. Prof. Whitfield suggests that the Dun Glen variety may possibly be a new species."

Elsewhere, too, it is stated by Hall and Whitfield[6] that this Triassic form from Dun Glen differs from the Jurassic specimens "in the more obtuse points of the star, and the filling up of the angles between the points, and also in the broader form of the elliptical figures on the articulating surfaces of the disks." These are just the differences between the stem-joints of *Extracrinus* and those of *Pentacrinus*, as explained above; and I am therefore disposed to think that this Triassic type with broader petals may be a true *Pentacrinus*, more especially as we have no knowledge of any European *Extracrinus* below the Lias.

It must be remembered that nearly all of these identifications are based upon the characters of the stem-fragments only, the calyx and arm-bases being but rarely preserved. Every one who has examined moderately long pieces of stem, whether recent or fossil, has noted the variation of characters which they present in different parts; and there has therefore been a general disposition not to place too much reliance on species of which only the stems are known. I have been surprised to find, however, in the case of

[1] Palæontology of the Upper Missouri, Invertebrates, part i. p. 67, pl. iii. fig. 2.

[2] *Proc. Acad. Nat. Sci. Philad.*, March 1858, p. 49.

[3] Report upon Geographical and Geological Explorations and Surveys west of the One Hundredth Meridian, in charge of First Lieut. Geo. M. Wheeler, vol. iv. part i., Palæontology, p. 162, pl. xiii. fig. 6,*a*.

[4] Eleventh Annual Report of the U. S. Geological and Geographical Survey of the Territories, embracing Idaho and Wyoming, 1879, pp. 626, 627.

[5] Report of the Fortieth Parallel Survey, Descriptive Geology, vol. ii. p. 711.

[6] *Ibid.*, vol. iv. p. 280, pl. vi. fig. 16.

recent types that when allowance is made for the different stages of growth, the characters of the stem are of much use in the distinction of species. This is especially the case if the number of internodal joints can be ascertained, which is not often possible, however, with fossil stems. But I am more disposed than I formerly was to accept the numerous species described by de Loriol and Quenstedt on the characters of the stem alone. Under these circumstances it is possible that more of the Continental species may eventually be found to occur in Britain, the number at present known being very small.

The geological range of individual species, both of *Pentacrinus* and of *Extracrinus*, seems to be rather limited, no species occurring in all three divisions of the Lias. Out of fifteen species of *Pentacrinus* which are found in the Middle and Upper Lias of Britain, only two are common to the two horizons. Neither of the two Lower Lias species reach the Middle Lias, though *Pentacrinus basaltiformis* does so on the Continent. This and *Pentacrinus psilonoti* are the only Continental species which have yet been recognised in the British Lias. One species of the Kimmeridge Clay, *Pentacrinus sigmaringensis*, also occurs in the White Jura of the Continent.

This agrees very well with the geographical distribution of the Pentacrinidæ in the recent seas, the four West Indian species, though abundant in the Caribbean Sea, not occurring elsewhere; while the remaining two Atlantic species have respectively been found at one and at three stations only. *Pentacrinus naresianus* was obtained in the West Pacific in lat. 29° 55′ S., and also in lat. 4° 33′ N. (or possibly 9° 26′ N.), and has the widest geographical range of any *Pentacrinus*, recent or fossil, that I am acquainted with. Like the Silurian Crinoids, therefore, the species of *Pentacrinus*, both recent and fossil, seem to be somewhat limited in their geographical range.

The genus has, however, a wider geographical range than *Metacrinus*, which is confined to the Pacific Ocean and the East Indian Archipelago. On the other hand, while fourteen species of *Metacrinus* are known, *Pentacrinus* is only represented by eight, together with the doubtful form which I have called *Pentacrinus* (?) *mollis* (Pl. XXXIII. figs. 7–10). The mutual relationships of these eight species are shown in the following table; and it will be seen that they fall into two very natural groups, which have the four Caribbean and the two Pacific species equally divided between them.

Genus *Pentacrinus*, Miller.

- The two outer radials and the first two joints beyond each axillary united by syzygies
  - Five cirri at each node.
    - Cirri large and stout, of thirty-five to fifty joints. Rays may divide five times.
      - Usually fifteen to eighteen internodal joints. The hypozygal does not share in the cirrus-sockets. Generally more than three joints between the irregular arm-divisions. Pinnule joints have forward projecting processes. — 1. *asterius*, Linn.
      - Six to eight internodal joints. The hypozygal shares in the cirrus-sockets. Only two or three joints between the regular arm-divisions. — 2. *müllerí*, Oersted.
    - Fifteen to twenty-five cirrus-joints. Rays only divide three times. Each division of two joints united by syzygy.
      - One or two internodal joints, . — 3. *maclearanus*, Wyv. Thoms.
      - Thirty-five to forty-five internodal joints. — 4. *wyville-thomsoni*, Jeffreys.
  - Two and three cirri alternately at successive nodes. Rays divide three times; each division of two joints united by syzygy. Four internodal joints. — 5. *alternicirrus*, n. sp.
- The two outer radials and the first two joints beyond them united by bifascial articulations.
  - Ten arms only. The third brachial a syzygy with angular syzygial faces. First pinnule on the second brachial. Eight to seventeen internodal joints. — 6. *naresianus*, n. sp.
  - Rays may divide three times. The second free brachial a syzygy. Pinnule on the first brachial.
    - Five to seven internodal joints. Nodal joints not enlarged, and the hypozygal sharing but little in the cirrus-sockets. Syzygial faces angular. — 7. *blakei*, n. sp.
    - Eleven or twelve internodal joints. Nodal joints enlarged and projecting, and the hypozygal grooved to receive the cirrus-bases. Syzygial faces nearly plane. — 8. *decorus*, Wyv. Thoms.

1. *Pentacrinus asterius*, Linn., sp. (Pl. XI.; Pl. XII. figs. 15–25; Pl. XIII.; Pl. XVII. figs. 7, 8).

1761. *Palmier marin*, Guettard, Mémoires de Mathématique et de Physique tirés des Registres de l'Academie Royale des Sciences, de l'année MDCCLV., Paris, 1761, p. 225.

1762. *Encrinus, capite stellato, ramoso dichotomo. Stipite pentagono-equisetiformi.*, Ellis, Phil. Trans., vol. lii. pt. i. for the year 1761, London, 1762, p. 358.

1766. *Isis asteria*, Linnæus, Systema Naturæ, ed. xii., Holmiæ, 1766, t. i. p. 1288.

1775. *Isis asterias*, Müller, Linne's Natursystem, nach der zwölften lateinischen Ausgabe, Nürnberg, 1775, Bd. ii. p. 742.
1788. *Isis asteria*, Linnæus, Systema Naturæ, ed. xiii., cura, J. F. Gmelin, Lipsiæ, 1788, t. i. pars vi. p. 3794.
1816. *Encrinus caput-Medusæ*, Lamarck, Histoire Naturelle des Animaux sans Vertèbres, t. ii., Paris, 1816, p. 435.
1820. *Pentacrinites vulgaris*, von Schlotheim, Die Petrefactenkunde, Gotha, 1820, p. 327.
1821. *Pentacrinus Caput-Medusæ*, Miller (pars), A Natural History of the Crinoidea, Bristol, 1821, p. 48, pl. i.
1834. *Encrinus caput-Medusæ*, de Blainville, Manuel d'Actinologie, Paris, 1834, p. 254.
1836. *Pentacrinus Caput-Medusæ*, Buckland, Geology and Mineralogy, London, 1836, p. 432, pl. 52, fig. 1.
1843. *Pentacrinus caput-Medusæ*, Müller (pars), Abhandl. d. k. Akad. d. Wiss. Berlin, Jahrg. 1841, p. 9, Taf. 1.
1845. *Pentacrinus Caput-Medusæ*, Austin[1] (pars), A Monograph on Recent and Fossil Crinoidea, Bristol, 1843–45, p. 111, pl. 14.
1856. *Pentacrinus caput-Medusæ*, Oersted, Forhandl. Skand. Naturf., 7de Möde i Christiania, 1856, p. 202.
1862. *Pentacrinus caput-Medusæ*, Dujardin and Hupé, Hist. Nat. des Zoophytes, Échinodermes, Paris, 1862, p. 181.
1864. *Cenocrinus Caput-Medusæ*, Wyville Thomson, The Intellectual Observer, August 1864, p. 3.
1864. *Pentacrinus asteria*, Lütken, Vidensk. Meddel. f. d. nat. Foren. i Kjøbenhavn, 1864, p. 207.
1865. *Pentacrinus* (*Neocrinus*) *asterias*, Wyville Thomson, Phil. Trans., vol. clv., 1865, p. 542.
1872. *Pentacrinus asteria*, Wyville Thomson, Proc. Roy. Soc. Edin., vol. vii. p. 765; and The Depths of the Sea, p. 435.
1877. *Pentacrinus asteria*, Wyville Thomson, The Atlantic, London, 1877, vol. ii. pp. 123–126.
1882. *Pentacrinus asteria*, P. H. Carpenter, Bull. Mus. Comp. Zoöl., vol. x. p. 168.

Dimensions.

Length of stem to twentieth node,	48 cm.
Greatest diameter of stem,	7 mm.
Longest cirrus (fifty joints),	70 „
Diameter of calyx across first radials,	11 „
Diameter of disk,	17 „
Length of arm (one hundred joints),	100 „
Length of distichal pinnule (twenty-five joints),	28 „
Length of first pinnule after tertiary axillary (thirteen joints),	12 „

Stem long, robust, and generally smooth. Outline pentagonal, with slightly rounded angles, but more circular in the lower part. Internodal joints thirteen to twenty-one (usually fifteen to eighteen) in number, with but slightly crenulated edges even in the upper part of the stem. Nodal joints marked by large, transversely oval cirrus-sockets, which occupy almost their whole height. The sockets have sharp, well defined rims, and are entirely filled by the articular facets. Cirri composed of thirty-five to fifty stout, smooth, and tolerably equal joints, with a small terminal claw and no opposing spine; though the ventral surface of the later joints is often marked by two or three blunt points.

Infra-nodal joints rarely grooved to receive the cirrus-bases, and then but slightly so. Lowest limit of the interarticular pores between the ninth and twelfth nodes.

[1] The Messrs. Austin and also Dujardin and Hupé give an undated reference to Parra's *Hist. Nat. Havannæ* p. 191, pl. 70, in which this type seems to have been mentioned by the name *Palma animal*. But I have been unable to consult the work, and can therefore do no more than make this reference to it.

Basals triangular or rhomboidal, not meeting laterally on the exterior of the calyx. The two outer radials united by syzygy. The grouping of the ray-divisions and the number of their component joints are somewhat irregular. Primary arms of two to six (usually three or four) distichal joints; secondaries of two to eighteen (usually seven to nine) palmar joints; tertiaries of six to fourteen joints, and occasionally another division after eight or ten joints more. The tertiary arms which divide are often only the two outer ones in each group of four, so that the distichal axillary bears six arms, viz., 2, 1; 1, 2; but there are sometimes "more than a hundred arms."[1] The first two joints beyond each axillary united by syzygy, with a pinnule on the epizygal. No other syzygies on the arms, which consist of about a hundred smooth, oblong joints, the outermost ones overlapping slightly. Distichal and palmar pinnules very large and stout, with thick lower joints, those of the later arm-divisions and of the free arms being much smaller. The joints of these large lower pinnules have the distal edge raised into a strongly marked keel which projects forward over the base of the next joint; and this feature recurs on all the pinnules of the arms, though it is less distinct in their middle and outer portions.

The perisome uniting the rays up to the level of the distichal axillaries is paved by large, closely set plates. Similar plates cover the ventral surface of the disk and arm-bases. Arm-groove moderately wide, and protected by numerous irregular plates. Pinnule-ambulacra have covering plates, but no definite side plates. Colour in spirit or dry, a light yellowish-brown.

Localities.—Various parts of the Caribbean Sea—Nevis, Martinique, Barbados, Guadeloupe (Dr. Schramm); off Saba Island, 320 fathoms (Captain Cole). This species was only once dredged by the U. S. Coast Survey steamer "Blake," cruise of 1878–79, No. 157, off Montserrat, 120 fathoms.

Remarks.—The specific name *caput-Medusæ*, which was originally bestowed by Lamarck on the West Indian *Pentacrinus* described by Guettard, was used by Miller, Goldfuss, Müller, and all later writers till the year 1864. In August of this year the late Sir Wyville Thomson[2] published a popular article on Sea Lilies, in which he expressed the opinion that the fossil *Pentacrinus briareus*, a widely different species from the recent *Pentacrinus caput-Medusæ*, "seems, however, to have a just claim to be recognised as the type of the genus *Pentacrinus*;" and he therefore proposed to give the generic name *Cenocrinus* to the West Indian species, for which he retained the original title *Caput-Medusæ*. Lütken,[3] however, reverted to the original specific designation employed by Linnæus,[4] and called the type *Pentacrinus asteria*. In the following year[5] Thomson referred to it as *Pentacrinus* (*Neocrinus*) *asterias*, Linn.; but he subsequently[6] gave up

[1] See Wyville Thomson, *The Intellectual Observer*, August 1864, p. 5.
[2] *The Intellectual Observer*, August 1864, p. 3.
[3] Om Vestindiens Pentacriner, *loc. cit.*, p. 207.
[4] Systema Naturæ, ed. xii., Holmiæ, 1766, t. i. p. 1288.
[5] *Phil. Trans.*, 1865, p. 542.
[6] *Proc. Roy. Soc. Edin.*, vol. vii., 1872, p. 765; and also The Depths of the Sea, p. 435.

both the generic names *Cenocrinus* and *Neocrinus* and described the type as *Pentacrinus asteria*, Linn., as Lütken had previously done.

It was clearly right to return to the specific name employed by Linnæus, although he was utterly at fault as regards the generic position of the type. But every writer on the subject, myself included, has used a wrong termination to the specific name. Linnæus wrote *Isis asteria*, which appears as *Isis asterias* in Müller's edition of the Systema Naturæ (Bd. ii. p. 742), published at Nuremberg in 1775; and this has been quoted by de Blainville and others. But when the species came to be referred to *Pentacrinus*, and the Linnean specific name was restored in place of *caput-Medusæ*, it should have been written *Pentacrinus asterius*, the expression *Pentacrinus asteria*, used by Lütken, Thomson, and myself being a false concord; for it is evident that the etymology of Linnæus's name *Isis asteria* is the adjective ἀστέριος, starry, and not the noun *Asteria*, cat's eye.

I am indebted for this tardy correction to the critical acumen of my friend Prof. F. Jeffrey Bell. But as it did not reach me till all the plates illustrating the type and most of the morphological section of the Report had been printed off, I have been unable to avail myself of it as fully as I should like to have done.

It is somewhat curious that this species, which for the greater part of a century was the only known living representative of the genus, should be comparatively so little known at the present time. But one specimen of it was ever dredged by the "Blake," whereas *Pentacrinus decorus* was obtained by the hundred; and even stem-fragments were very rarely met with. One specimen was taken by Captain Cole of the telegraph steamer "Investigator," in 320 fathoms off Saba Island; and it is now in the zoological collection of the Natural History Museum. The agents of Mr. Damon of Weymouth have been successful in procuring several excellent specimens, which have been bought by different museums, but I have not been able to examine more than a very few of them.

The preceding description is based upon the characters presented by the following examples of the type:—*A*. Miller's original specimen from Nevis, now in the geological department of the Natural History Museum. *B*. One dry specimen and two others in spirit, all in the zoological department of the same museum. *C*. One dry specimen in the Hunterian collection of the Royal College of Surgeons. *D*. Two dry specimens obtained by Dr. Carpenter and Sir Wyville Thomson from Mr. Damon of Weymouth. I have not made a personal inspection of Guettard's original specimen, but when Mr. Percy Sladen was in Paris for the purpose of investigating the collection of Asterids in the museum, he was permitted by Prof. Perrier to examine it on my behalf; and from the notes of its characters which he was kind enough to give me, together with the original figures of Guettard, I have no doubt that it is a fairly normal specimen of the type.

Pentacrinus asterius is much more robust than any of the other recent species of the genus, none of which have such wide stem-joints, though these are not so large as in some fossil species. The stem also seems to grow to a greater length than that of any other recent

type but the slender *Pentacrinus decorus*. But as in so many other species it was liable to fracture just below a node, so that the individual led a semi-independent existence; for I have one stem-fragment in which the lowest joint is decidedly worn and its central canal closed up by a small round boss which projects above the remaining surface of the joint.

The length of the internodes in *Pentacrinus asterius* distinguishes it at once from *Pentacrinus mülleri*, its nearest ally, which has similar long and stout cirri; while the infra-nodal joint is usually somewhat grooved to receive the cirrus-bases. This is but rarely the case in *Pentacrinus asterius*, and then only to the slightest possible extent, so that the cirrus-socket is practically limited to the articular facet, without any extension either upwards or downwards. The stem of *Pentacrinus asterius* is thus very readily identified, and the same may be said of the arms, which is rarely the case with the other species of the genus, unless the ventral groove be examined. For the peculiar features of the pinnules are very characteristic. They are well shown in Miller's figure[1] and likewise in those given by Müller,[2] who specially referred to the projections from the ends of the pinnule-joints. The great thickness of the basal joints in the distichal and palmar pinnules, especially the former, is a somewhat unusual character in a *Pentacrinus*. A trace of it may be seen in some forms of *Pentacrinus mülleri;* but in most species of the genus the lower joints of the first pinnules are laterally compressed, and lie close against the arm. They thus present a great contrast to the almost cubical or prismatic basal joints of the first pinnules in *Metacrinus* (Pl. XLIII. figs. 2, 4). The preceding description differs in one important respect from those given by Müller and Lütken. The former author spoke of the union between the second and third radials as an articulation, but was somewhat obscure about its nature. He was not able to separate the two joints, but seems to have inferred that they were united by a bifascial articulation such as he found in *Antedon rosacea*.[3] While, however, he stated expressly that the latter type has no muscles between the second and axillary radials, he described and figured muscles as existing in this position in *Pentacrinus caput-Medusæ*.[4] This led Lütken to state[5] that the existence of an articulation between the two outer radials of *Pentacrinus asterius* was an important character separating it from *Pentacrinus mülleri*, which has these joints united by syzygy. Neither he nor Müller, however, had ever actually separated the joints, specimens being then too valuable, or the real state of the case would have become evident at once. This was first discovered by Sir Wyville Thomson,[6] who pointed out that there is really a syzygy between the two outer radials of *Pentacrinus asterius*. In this respect, therefore, this species resembles *Pentacrinus mülleri*, instead of differing from it as was supposed by Lütken. But unfortunately Sir Wyville totally misconceived the real character of Oersted's species, and confounded it with the one previously described by

[1] *Op. cit.*, p. 51, pl. ii. fig. 5.
[2] Bau des Pentacrinus, p. 43, Taf. ii., iii.
[3] *Ibid.*, p. 26, Taf. ii. fig. 12.
[4] *Ibid.*, p. 30, Taf. ii. fig. 8.
[5] Om Vestindiens Pentacriner, *loc. cit*, p. 202.
[6] *Proc. Roy. Soc. Edin.*, vol. vii., 1872, p. 766.

himself under the name of *Pentacrinus decorus*. He was thus led to state that while the two outer radials of *Pentacrinus asterius* are united by syzygy, those of *Pentacrinus mülleri* are articulated, a mistake almost the opposite of that made by Lütken. It is not difficult to understand how Müller's error arose; for the line of syzygy is not dotted as it is in the Comatulæ, where the apposed faces are marked by radiating ridges. There is little or nothing of this striation on the syzygial surface of *Pentacrinus asterius* (Pl. XII. figs. 18, 21); and the muscular unions of the remaining calyx- and arm-joints are so very close that there is hardly any external character by which the syzygy between the two outer radials may be detected. Its presence is evident enough between the two joints following each axillary, as they are shorter than their successors. But nothing of this kind appears in the case of the radials, and as they are very apt to become slightly separated at the edges I have found it almost impossible, especially in dry specimens, to determine the real nature of the union without separating the joints. This was done by Sir Wyville Thomson, whose preparations are figured in Pl. XII. figs. 15–25.

The basals of *Pentacrinus asterius* are of very variable size, like those of *Pentacrinus decorus*, though not to the same extent. They are sometimes small, rounded knobs, not meeting one another upon the exterior of the calyx; or larger and more prominent, meeting their fellows in the re-entering angles beneath the radials; but they never form a completely closed ring of triangular or pentagonal plates flush with the radials, as they do in *Pentacrinus wyville-thomsoni*, *Pentacrinus alternicirrus*, and some other species (Pl. XVIII. figs. 1–3; Pl. XIX. figs. 1, 6, 7; Pl. XX. figs. 2, 3; Pl. XXV.).

Lütken, Thomson, and others have endeavoured to establish as one of the characters of *Pentacrinus asterius* that the nodal joints of the stem are low and simple, while those of *Pentacrinus mülleri* and *Pentacrinus decorus* are thick and double, consisting of two parts united by syzygy. This is not really the case, however. In all recent Pentacrinidæ the nodal joints proper, *i.e.*, those which are pierced by the canals lodging the cirrus-vessels, are always single and united by syzygy to those next below them. But the line of junction is sometimes so nearly obliterated as to be only visible with difficulty; while in other cases, such as *Pentacrinus asterius* (Pl. XIII. fig. 8), it is hardly distinguishable from the ordinary junction lines between the internodal joints, which are crenulated much less than usual.

The following may therefore be regarded as the special marks of *Pentacrinus asterius*:—a robust stem with long internodes and wide cirrus-sockets; the ray-divisions rather irregular in number and grouping; the projections of the pinnule-joints.

Little is known about the range of *Pentacrinus asterius*, either in depth or in space. Examples have been obtained off Barbados, Guadeloupe, Martinique, Montserrat, Nevis, and Saba Island; while the only two cases in which the depth is known with certainty are respectively 120 and 320 fathoms. Like the three other West Indian species, it is not known to occur out of the Caribbean Sea.

2. *Pentacrinus müllèri*, Oersted, 1856 (Pls. XIV., XV.; Pl. XVII. figs. 9, 10).

1821. *Pentacrinus caput-Medusæ*, Miller (pars), A Natural History of the Crinoidea, p. 46.
1843. *Pentacrinus caput-Medusæ*, Müller (pars), Abhandl. d. k. Akad. d. Wiss. Berlin, 1843, p. 185.
1845. *Pentacrinus Caput-Medusæ*, Austin (pars), A Monograph of Recent and Fossil Crinoidea, p. 111.
1856. *Pentacrinus Müllèri*, Oersted, Forhandl. Skand. Naturf., 7de Möde i Christiania, 1856, p. 202.
1864. *Pentacrinus Müllèri*, Lütken, Vidensk. Meddel. f. d. nat. Foren. i Kjøbenhavn, 1864, Nr. 13–16, p. 207.
1865. *Pentacrinus* (*Neocrinus*) *Müllèri*, Wyville Thomson, Phil. Trans., 1865, vol. clv. p. 542.
1882. *Pentacrinus müllèri*, P. H. Carpenter, Bull. Mus. Comp. Zoöl., vol. x., No. 4, p. 170.
non Pentacrinus Müllèri, Wyville Thomson, in Proc. Roy. Soc. Edin., vol. vii. p. 776; and in The Depths of the Sea, p. 442.
non Pentacrinus Müllèri, Agassiz and Pourtalès, in Bull. Mus. Comp. Zoöl., vols. v., vi.

Dimensions.

Total length of largest specimen,[1]	32 cm.
Greatest length of entire stem, rounded off at sixteenth node,	185 mm.
Shortest stem, rounded off at twelfth node,	117 „
Diameter of stem,	6 „
Longest cirrus (forty-three joints),	56 „
Diameter of calyx,	11 „
Diameter of disk,	14 „
Length of arm (one hundred joints),	160 „
Length of pinnule on first free brachial (fifteen joints),	18 „
Length of pinnule from middle of arm (twenty-one joints),	20 „

Stem robust, but of no great length. Outline pentagonal, with rounded angles and smooth surface. Internodal joints four to eleven (usually six to eight) in number, with but slightly crenulated edges, even in the upper part of the stem. Cirrus-sockets transversely oval and not reaching the upper edges of the nodal joints, but extending more or less downwards on to the infra-nodals, which are grooved to receive the cirrus-bases.

Cirri composed of thirty to forty-five stout, smooth, and tolerably equal joints, the later ones of which may have a couple of small, blunt projections on the ventral side. Terminal claw small and without an opposing spine. Lowest limit of the interarticular pores between the fourth and eighth nodes.

Basals variable; sometimes pentagonal, forming a closed ring; sometimes triangular or rhomboidal, barely in contact by their lower angles; and sometimes quite small, not meeting at all upon the exterior of the calyx. Rays and their subdivisions not separated by perisome, but in close lateral contact, the joints as far as the lowest free brachials beyond the tertiary axillaries having their sides more or less flattened, often very much so. The two outer radials united by syzygy. There are usually six or eight arms on

[1] The total length of this individual, which was obtained by Captain Cole, and is now in the Natural History Museum, is slightly greater than that of the largest specimen dredged by the "Blake." The stem, which is 19 cm. long, is broken just below the twenty-first node. But in the same bottle there is a fragment which appears to be the bottom part of this stem, and has the lowest nodal joint closed in the usual way.

each ray in the following order—2,1; 1,2; or 2,1,1; 1,1,2, the axillaries being limited to the outer arm of each successive pair. Primary arms of one to three (usually two) distichal joints, which are united by syzygy. Secondary arms of two to seven palmar joints, usually three. There may be one, or more rarely two, further divisions, which are usually of three joints each, but may have five or six.

The first two joints after each axillary are united by syzygy, the epizygal, when not itself an axillary, bearing the first pinnule. No other syzygies on the arms, which consist of about one hundred smooth, oblong joints, the lowest of which have flattened sides, and are sometimes more or less tubercular, while the outer ones overlap slightly. The first pinnules are somewhat longer and stouter than the following ones, after which the size again increases. The pinnules have a smooth, sharp dorsal edge, and are generally composed of flattened joints, the lowest of which are slightly wider than their successors, and are sometimes markedly prismatic.

The disk bears numerous scattered calcareous granules, but no regular pavement of plates, and there is no plated perisome between the rays. Arm-groove moderately wide, and closely covered by numerous, small, irregular plates. Pinnule-ambulacra have covering plates and ill defined side plates.

Colour in spirit, white or brownish-white, somewhat darker on the pinnules.

Localities.—Guadeloupe, St. Croix, St. Thomas, Barbados; between Saba and Eustatius Islands, 531 fathoms (Captain Cole).

The dredgings of the U. S. Coast Survey steamer "Blake," cruise of 1877–78, off Havana; 175 fathoms.

Cruise of 1878–79. No. 100, off Morro Light; 250 to 400 fathoms. No. 101, off Morro Light; 175 to 200 fathoms. No. 157, off Montserrat; 120 fathoms. No. 171, off Guadeloupe; 183 fathoms; bottom temperature, 55½° F. No. 193, off Martinique; 169 fathoms; fine sand, dark mud, and shells; bottom temperature, 51° F. No. 218, off St. Lucia; 164 fathoms; bottom temperature, 56° F. No. 269, off St. Vincent; 124 fathoms; bottom temperature, 57½° F. No. 274, off Barbados; 209 fathoms; fine sand and ooze; bottom temperature, 53½° F. No. 280, off St. Charles Lighthouse, Barbados; 221 fathoms; Globigerina sand; bottom temperature, 50½° F. No. 283, off Barbados; 237 fathoms; hard bottom; bottom temperature, 49° F. No. 291, off Barbados; 200 fathoms; flat calcareous stones; bottom temperature, 49¾° F. No. 295, off Barbados; 180 fathoms; hard bottom; bottom temperature, 50¾° F. No. 296, off Barbados; hard bottom; 84 fathoms; bottom temperature, 61½° F. No. V. (Bartlett), Santiago de Cuba; 288 fathoms.

Remarks.—This species was discovered by the Danish naturalist Oersted, who brought an example to Europe from the Danish possessions in the West Indies. It was exhibited in the year 1856 at the meeting of Scandinavian naturalists in Christiania,[1] and a brief

[1] *Forhandl. Skand. Naturf.*, 7de Möde i Christiania, 1856, p. 202.

preliminary diagnosis of it, together with a similar notice of *Pentacrinus caput-Medusæ* (*asterius*), was published in the report of the meeting. Such was the rarity of these Crinoids that Oersted's discovery of a new species attracted but little attention, although an example of it from Guadeloupe had long been contained in the collection of the Geological Society of London, and had been referred by Müller to *Pentacrinus caput-Medusæ*. These facts seem to have escaped the notice of Sir Wyville Thomson, who himself described a new species (*Pentacrinus decorus*) in 1864, and spoke of it and *Pentacrinus caput-Medusæ* as the only two known living species of the Stalked Crinoids.[1]

Early in the next year, however, an elaborate memoir on the West Indian Pentacrinidæ was published by Dr. Lütken, which has served as the basis of most of the subsequent work on the genus. Not only did he make a careful examination of Oersted's original specimen of *Pentacrinus mülleri*, but he found that two other individuals in the Copenhagen Museum were identical with it; he was thus able both to discover some more important points of difference between *Pentacrinus mülleri* and the Linnean type, and also to work out some of the individual variations in the characters of *Pentacrinus mülleri* as defined by Oersted.

In his preliminary diagnoses of *Pentacrinus asterius* and *Pentacrinus mülleri*, Oersted had already indicated the differences in the numbers of joints composing the arm-divisions of the two species. This character was still further investigated by Lütken,[2] who pointed out its influence upon the external appearance of the animal. Relying chiefly upon the figures of *Pentacrinus asterius* which were given by Miller and Müller, he showed that the numbers of joints in the successive arm-divisions were respectively 5 or 6, 9 or 10, and 12. In *Pentacrinus mülleri*, on the other hand, these numbers are 2; 2–4; 3; and 3–5; and it is almost always only the two outer arms on the ray which divide at all, so that the arms of any ray with secondary axillaries would be represented by the expression 2,1; 1,2; and by 2,1,1; 1,1,2, if tertiary axillaries be present. This is a sort of indication of the inequality of the arm-divisions of *Extracrinus*, and is tolerably constant in *Pentacrinus mülleri*, though not limited to that species, for it is visible in *Pentacrinus asterius*, as detected by Quenstedt[3] in Miller's figure.

After the publication of Lütken's Memoir, *Pentacrinus mülleri*, Oersted, came to be recognised as a type distinct from the old *Pentacrinus asterius*. It was referred to by Sir Wyville Thomson,[4] together with *Pentacrinus asterius* and *Pentacrinus decorus*, so that he evidently regarded it as distinct from both of them. Later on, however, he seems to have come to the conclusion that his *Pentacrinus decorus* was identical with Oersted's species. For having previously said that *Pentacrinus asterius* and *Pentacrinus decorus* were the only two known living species of the genus, he made nearly the same

[1] Sea Lilies, *The Intellectual Observer*, August 1864, p. 1.
[2] Om Vestindiens Pentacriner, *loc. cit.*, p. 203.
[3] Encriniden, p. 190, Tab. 97, fig. 3.
[4] *Phil. Trans.*, vol. clv., 1865, p. 542.

statement concerning *Pentacrinus asterius* and *Pentacrinus mülleri*.[1] He likewise repeated most of his original description of *Pentacrinus decorus* as a diagnosis of *Pentacrinus mülleri*, with a reference under the latter name to the specimen which he had before him when describing *Pentacrinus decorus*. He stated that the two outer radials of *Pentacrinus asterius* were united by syzygy, and further added that "the arrangement of the joints and the syzygies in the cup is the same in *Pentacrinus mülleri* as in *Pentacrinus asteria*, only the syzygy between the second radial and the radial axillary is not so complete." This passage obviously refers to a ligamentous articulation as distinguished from a true syzygy on the one hand, and from a muscular joint on the other; and it is by no means in accordance with Lütken's very positive statements as to the presence of a true syzygy between the two outer radials of *Pentacrinus mülleri*. Neither does Sir Wyville's description of the nodes as occurring about every twelfth joint agree with Lütken's diagnosis, which records only four to ten internodal joints in *Pentacrinus mülleri*. As a matter of fact there are eleven or twelve internodal joints in *Pentacrinus decorus*, and there is no syzygy at all between the two outer radials, but only a bifascial articulation such as occurs in the majority of the Neocrinoidea, and has often been wrongly spoken of as a syzygy, though clearly distinguished from it by Müller. This is shown in figs. 3 and 6 on Pl. XXXIV., a copy of which was lettered "*Pentacrinus mülleri*, Oersted," by Sir Wyville Thomson. I cannot but think, however, that if he had lived to work out the "Blake" collection more fully than he was able to do before his health gave way, he would have retained his original views as to the distinctness of his *Pentacrinus decorus* from *Pentacrinus mülleri*, Oersted. The result of this confusion was that the numerous specimens of *Pentacrinus decorus* which were dredged by the "Bibb" and the "Blake" in the Gulf Stream and in the Caribbean Sea were referred to *Pentacrinus mülleri* by Pourtalès and Agassiz.[2] The two species have really no sort of resemblance to one another, differing in all the characters of the stem, the cirri, the calyx, and the arms.

The foregoing description is based upon an examination of four specimens from the "Blake" collection, two purchased by Sir Wyville Thomson from Mr. Damon, one in the collection of Sir Rawson Rawson, and lastly that in the Museum of the Geological Society of London, which is mentioned by both Miller and Müller as *Pentacrinus caput-Medusæ*.

Pentacrinus mülleri is readily distinguished from *Pentacrinus asterius*, which is its nearest ally, by the shortness of the internodes and the modification of the hypozygal joints, which, however, is far less marked than in *Pentacrinus decorus*. The basals generally form a complete ring; while the branching of the arms is much more regular

[1] *Proc. Roy. Soc. Edin.*, vol. vii. p. 766; and The Depths of the Sea, pp. 434, 435; see also The Atlantic, vol. ii. p. 126.

[2] *Bull. Mus. Comp. Zoöl.*, vol. i. p. 357; *Ibid.*, vol. v. pp. 56 and 214; *Ibid.*, vol. vi. p. 296.

than in *Pentacrinus asterius*. There are fewer joints between the successive axillaries, and the characters of the pinnules are altogether different. In these latter points *Pentacrinus mülleri* closely resembles *Pentacrinus macleayanus* (Pl. XVI.), *Pentacrinus wyville-thomsoni* (Pl. XVIII. fig. 1), and *Pentacrinus alternicirrus* (Pl. XXV.). But the first named has only one or two internodal joints in the stem, while *Pentacrinus wyville-thomsoni* has from thirty to forty-five, so that they are both readily distinguishable from *Pentacrinus mülleri;* while the grouping of the cirri on the stem of *Pentacrinus alternicirrus* is sufficient to distinguish this species at once.

So far as I can judge from the material at my disposal, *Pentacrinus mülleri* is certainly the most variable of the Pentacrinidæ with the exception of *Pentacrinus decorus*. The stem does not seem to reach the length which it attains both in the latter species and in *Pentacrinus asterius*. In one instance it is rounded off at the twelfth node, only 135 mm. from the calyx, and Rhizopods are attached to the under surface of the lowest nodal joint. Another stem tapers gradually downwards from a width of 5 mm. at the calyx to 3 mm. at the sixteenth node, where it is rounded off 185 mm. from the calyx.

The length of the internodes varies a good deal in different individuals, though as a rule it is tolerably constant in any given stem. The component joints are usually thick and thin alternately. This is very marked in the specimen represented in Pl. XIV., though not well shown in the figure; while in other cases the joints are more equal in height, as shown in Pl. XV. fig. 4. This figure should be compared with the corresponding one of *Pentacrinus asterius* (Pl. XIII. fig. 8), in which the cirrus-sockets are not so deeply hollowed as they are in *Pentacrinus mülleri*. Their shape, too, is somewhat variable in the latter type. In some stems (Pl. XV. fig. 4) they are transversely oval as in *Pentacrinus asterius* (Pl. XIII. figs. 4, 8), though not reaching so near the top of the nodal joint. But they always extend slightly downwards on to the hypozygal, which is not the case in that species. In other examples, however, the hypozygal is deeply grooved to receive the bases of the cirri, and the sockets thus become more circular in form; so that it appears as if the cirri were borne conjointly by the two syzygial joints. This has been described as an important difference between *Pentacrinus mülleri* and *Pentacrinus asterius*, but erroneously so; for the whole of the articular surface is always on the nodal joint, which is the only one pierced by the canals lodging the cirrus-vessels.

The cirri, though always stout, are considerably shorter in some forms than they are in others; and while some of them have quite smooth terminal joints, those of other individuals bear small blunt processes which never, however, reach to the size of a spine.

The "Blake" collection includes a curious fragment of a stem which had broken between a nodal joint and the first joint of the internode above it. The upper part of the stem and the calyx are missing; but six irregularly shaped joints have been added above the node. One would like to know whether this reparation would ever have resulted in the formation of a new calyx and arms. Such an extensive reparation

seems scarcely possible, though the development of a new visceral mass inside the calyx is not uncommon.

As in *Pentacrinus asterius*, there is a considerable variation in the development of the basals. In the Copenhagen specimens described by Lütken, and in some of those which I have examined, they are pentagonal in outline and form a closed ring separating the radials from the top stem-joint. In other forms they are more prominent and rhomboidal or triangular in shape, but only just meeting one another in the re-entering angles of the calyx (Pl. XIV.; Pl. XV. fig. 2); while in Sir Rawson Rawson's specimen they are small and inconspicuous (Pl. XV. fig. 1), as in some varieties of *Pentacrinus decorus* (Pl. XXXVI.).

The number of arms may vary from thirty-five to forty-five, some individuals occasionally having ten arms to the ray. Generally, though not invariably, the axillaries are limited to the outer arm of each pair in the manner already described; but I have not seen any individual in which the six- or eight-armed arrangement is constant on every ray.

As there are very few joints separating the axillaries, there is comparatively little room for the arms, the bases of which are therefore more or less flattened laterally, both in the outer and in the inner parts of the rays. In fact, wherever an axillary occurs the two arms which it bears have their inner faces flattened, while the outer sides of the rays are flattened continuously from the second radials to as far as some six or eight joints beyond the fifth axillary.

This feature is especially marked in two fine specimens from the "Blake" collection, which are also distinguished by the shape of their lower pinnule-joints. One is from Martinique and the other from Barbados. The calyx and arm of the former are represented on Pl. XV. figs. 2, 3. The outer edges of the joints from the second radial onward are produced somewhat sharply upwards, and fit closely against those of adjacent joints. This is less prominent in the Barbados specimen, which shows an occasional tendency towards carination of the arm-bases. The other form is remarkable for the abnormal condition of one of its rays, as shown in Pl. XV. fig. 2. The third radial is articulated to the second instead of being united to it by syzygy. But it is itself a syzygial joint; so that there are primitively four radials, a character which indicates a tendency to variation in the direction of *Metacrinus* with its five or eight primitive radials (Pl. XXXIX. fig. 1; Pl. XLVI.). The pinnules of these two individuals are also different from those of other examples of the type. They are generally composed of moderately broad, flattened joints, the lowest of which are somewhat stouter than their successors. But in the two "Blake" specimens the pinnules are less flattened than usual, and the lower joints markedly trihedral in form, recalling, though in a less degree, the prismatic shape of the pinnules, which is characteristic of *Metacrinus* (Pl. XXXIX. fig. 1; Pl. XLIII. fig. 4).

The plating of the disk of *Pentacrinus müllerí* (Pl. XVII. fig. 10), like that of

Pentacrinus decorus (Pl. XXXIV. fig. 2), is far less complete than in *Pentacrinus asterius*. There is no trace of the large polygonal plates on the perisome between the rays which we find in the latter species (Pl. XIII. fig. 1), and those on the ventral surface of the disk are small and scattered, often being mere granules. The ambulacral skeleton too is imperfectly developed. The covering plates of the pinnules do not rest upon distinct side plates, but only upon an almost undifferentiated limestone band (Pl. XV. figs. 8, 9; Pl. XVII. fig. 9).

3. *Pentacrinus maclearanus*, Wyville Thomson, 1877 (Pl. XVI.; Pl. XVII. fig. 1).

1877. *Pentacrinus maclearanus*, Wyville Thomson, The Atlantic, vol. ii. pp. 123–126.

Dimensions.

Total length (*fide* C. W. T.),	13·00 cm.
Length of stem, rounded off at twelfth node,	34·00 mm.
Diameter of stem,	5·25 „
Longest cirrus (twenty-five joints),	28·00 „
Diameter of calyx,	9·00 „
Length of arm (sixty-eight joints),	80·00 „
Length of pinnule on first free brachial (ten joints),	7·00 „
Length of pinnule from middle of arm (fifteen joints),	14·00 „

Description of an Individual.—Stem short and pentagonal, with rounded angles, terminating below at the twelfth node. The internodes consist of only one or two comparatively thin joints. Nodal joints thicker, with enlarged and prominent angles; the cirrus-sockets, occupying almost their whole height, are circular or slightly oval in form, with a well-defined rim which extends downwards on to the infra-nodal for a variable distance. The cirri consist of twenty to twenty-five stout joints of tolerably equal size, with a small terminal claw and no opposing spine. Interarticular pores scarcely visible.

Basals rhomboidal, just in contact laterally, and extending slightly downwards over the uppermost stem-joints. Rays and their subdivisions in close lateral contact, the joints as far as the tenth or twelfth brachial having flattened sides. The two outer radials united by syzygy. Primary and secondary arms each of two joints also united by syzygy. Total number of arms thirty-one, *i.e.*, usually six to each ray in the following order —2, 1; 1, 2; palmar axillaries being generally developed only on the two outermost of the four secondary arms. A tertiary axillary in one ray. The two lower brachials united by syzygy, the epizygal bearing a pinnule. No other syzygies on the arms, which consist of about seventy short and wide, oblong joints, overlapping very slightly at the base.

The lowest pinnules are much shorter than their successors, and have only ten or twelve joints, the basal ones being trihedral and the outer ones flattened. The middle pinnules much longer, with about fifteen more rounded joints.

The disk is only partially visible, but seems to have a tolerably regular pavement of small plates. Arm-groove exceedingly narrow, the ambulacral plates being limited to the pinnule-bases. The pinnules have well defined covering plates with occasional faint indications of side plates.

Colour in spirit, brownish-white.

Locality.—Station 122, August 10, 1873; lat. 9° 5′ N., long. 34° 50′ W.; 350 fathoms; red mud. One specimen.

Remarks.—The leading characters of this elegant species were well described by Sir Wyville Thomson in The Atlantic. Its nearest allies are *Pentacrinus mülleri* (Pl. XIV.), *Pentacrinus wyville-thomsoni* (Pl. XVIII. fig. 1), and *Pentacrinus alternicirrus* (Pl. XXV.), all of which it resembles very closely in the regularity and grouping of the arm-divisions. The stem, however, is totally different from that of *Pentacrinus wyville-thomsoni* with its long internodes, and the number of arms is also greater than is usually the case in this species. *Pentacrinus mülleri* and *Pentacrinus alternicirrus* approach it most closely, having relatively short internodes; but the arrangement of the cirri on the stem of the latter species distinguishes it at once. *Pentacrinus maclearanus* closely resembles some specimens of *Pentacrinus mülleri* in the shape of the nodal joints; but, apart from the characters of the internodes, it is readily identified by the unusual shortness of its lowest pinnules and the more rounded form of the joints in the later ones.

The close approximation of the nodal joints, and the downward curvature of the cirri, together with the slight downward extension of the basals and the grouping of the arms, are of interest as recalling the Liassic *Extracrinus briareus*.

Only four cirri are present at one of the nodes, the fifth socket being totally absent. This indicates a variation in the direction of *Pentacrinus alternicirrus*, which has only two or three cirri at each node (Pl. XXVI. figs. 1–3).

4. *Pentacrinus wyville-thomsoni*, Jeffreys (Pl. XVII. figs. 2–6; Pls. XVIII.–XXIV.; Pl. LVII. fig. 1).

1870. *Pentacrinus Wyville-Thomsoni*, Jeffreys, Proc. Roy. Soc., 1870, vol. xix. p. 157.

1872. *Pentacrinus wyville-thomsoni*, Wyville Thomson, Proc. Roy. Soc. Edin., vol. vii. p. 767; and The Depths of the Sea, p. 444.

Dimensions.

Total length,	24·00 cm.
Longest stem, rounded off at seventh node,	155·00 mm.
Shortest stem, rounded off at fifth node,	80·00 „
Diameter of stem,	3·50 „
Longest cirrus (nineteen joints),	24·00 „
Diameter of calyx,	7·20 „
Diameter of disk,	9·75 „
Length of arm (seventy joints),	100·00 „
Length of pinnule on first free brachial (ten joints),	10·00 „
Length of pinnule from middle of arm (twenty-one joints),	24·00 „

N.B.—Examples of this species have been distributed to several museums, and only a few have come into my hands; so that the first three of the measurements given above must not be taken as indicating the whole range of variation throughout all the individuals which were dredged by the "Porcupine."

Stem smooth and moderately robust, but of no great length. The upper part is pentagonal with rounded angles; but the lower portion of an old stem is almost perfectly circular. Thirty to forty, and occasionally more, internodal joints with crenulated edges which are less distinct below. Nodal joints enlarged, with sharp angular ridges which stand out prominently between the cirrus-sockets. These are transversely oval, and occupy the whole height of the nodal joint, which projects outwards over the upper edge of the infra-nodal, while the supra-nodal is slightly grooved to receive the bases of the stout cirri. These consist of about eighteen tolerably equal, smooth, and thick joints, the lowest of which are broader than their successors, especially in mature individuals. Terminal claw small, without an opposing spine. The lowest limit of the interarticular pores is a little on either side of the fourth node.

Basals pentagonal, but sometimes approaching the triangular, wider than high, and forming a closed ring. The rays and their subdivisions in close lateral contact, the first five or six joints after the distichal axillary having flattened sides. The two outer radials united by syzygy. Fourteen to twenty-two arms, distichal axillaries being often absent, and palmars very rare. Primary and secondary arms each of two joints united by syzygy; the first two brachials united in the same way, the epizygal bearing a pinnule. The arms of about seventy smooth, oblong joints in which syzygies are very rare.

The first pinnules quite short, consisting only of nine or ten joints, the lowest of which are broad and flat, the later ones longer and more slender. The following pinnules increase rapidly in size, and soon become long and tapering, consisting of about twenty smooth, elongated joints, the lowest of which are slightly flattened. Disk completely covered with a pavement of small plates, as is the brachial perisome above the muscular bundles. Arm-groove moderately wide, and bordered by a discontinuous series of ambulacral plates. The pinnule-ambulacra have covering plates, but very ill defined side plates.

Colour grass-green, becoming white in spirit, which acquires a purplish-red tinge.

Locality.—H.M.S. "Porcupine," 1870. Station 17; lat. 39° 42′ N., long. 9° 43′ W.; 1095 fathoms; ooze; bottom temperature, 39°·7 F. About twenty specimens.

Also the "Talisman," 1883; off the Morocco Coast: and again off Rochefort; lat. 45° 59′ 30″ N., long. 6° 29′ 30″ W. of Paris; 1500 metres (800 fathoms).

Remarks.—This fine species was first obtained by Dr. Gwyn Jeffreys during the "Porcupine" expedition of 1870; and it was dedicated by him to his friend and colleague Sir Wyville Thomson in the general account of the voyage which was published in the

Proceedings of the Royal Society. It was not described, however, till the year 1872, when Sir Wyville contributed a notice of the "Porcupine" Crinoids to the Royal Society of Edinburgh; and in the following year he reproduced this description in The Depths of the Sea, together with a woodcut which gives a very fair idea of the principal characters of the type. All the entire specimens obtained were dredged at Station 17; but a few fragments of stem and arms were also met with at Station 17A (740 fathoms), together with ten specimens of *Antedon lusitanica*. Thirty specimens were recently dredged by the "Talisman" in 1500 metres off Rochefort. Dr. Gwyn Jeffreys[1] records that "portions of the arms occurred in several other of the 'Porcupine' dredgings on the Lusitanian coasts; and joints of apparently the same species have been found by Prof. Seguenza in the Zanclean formation or older Pliocene near Messina." The latter point, however, can hardly be properly decided without a careful study of both types.

In the structure of the ray-divisions and arms, *Pentacrinus wyville-thomsoni* is closely related to *Pentacrinus müllleri*, *Pentacrinus maclearanus*, and *Pentacrinus alternicirrus*, especially the latter; but it is at once distinguished from them all by the shape of the nodal joints, the short stout cirri which they bear, and the great length of the internodes which separate them. It is also remarkable for the manner in which the stem ends below in a nodal joint which is closed up beneath and rounded off, as shown in Pl. XXII. fig. 27. According to Sir Wyville Thomson[2] "all the stems of mature individuals of this species (which were dredged by the 'Porcupine') end uniformly in a nodal joint, surrounded with its whorl of cirri, which curve downwards into a kind of grappling root (Pl. XIX. fig. 1). The lower surface of the terminal joint is in all smoothed and rounded, evidently by absorption, showing that the animal had for long been free" (Pl. XXII. fig. 27). The positions of this terminal nodal joint and the corresponding length of stem in three individuals which I have examined are as follows:—stem 80 mm. long, terminating at the fifth node; stem 90 mm. long, terminating at the sixth node; stem 155 mm. long, terminating at the seventh node.

The zoologists of the "Talisman" claim to have proved, however, that Sir Wyville Thomson was wrong in his belief that the individuals dredged by the "Porcupine" were leading a semi-free existence, loosely rooted in the soft mud. In one of a series of popular articles by Mons. H. Filhol,[3] a member of the "Talisman" expedition, it is stated that Sir Wyville came to this conclusion after having examined *one* of the "Porcupine" specimens; and a free translation is given of the last sentence of the paragraph just quoted, from which, however, the words "in all" are entirely omitted. It is thus made to appear as if Sir Wyville had drawn his conclusions from the condition of only one example of *Pentacrinus wyville-thomsoni*, which is very far from being the case; while he also stated in the next paragraph to that quoted by Filhol that he had remarked

[1] *Proc. Roy. Soc.*, 1870, vol. xix. p. 157.

[2] *Proc. Roy. Soc. Edin.*, vol. vii. p. 767; The Depths of the Sea, p. 444.

[3] Explorations sous-marines, Voyage du "Talisman," *La Nature*, No. 568, April 19, 1884.

the same character "as occurring in some specimens of *Pentacrinus müllerí*," *i.e.*, the type now known as *Pentacrinus decorus*.

Filhol continues, however, "nous avons constaté, après avoir remonté des débris de roches, que ces animaux vivaient, contrairement à ce que l'on avait cru pouvoir supposer, complètement fixés par des cirres recourbés se détachant de l'articulation terminale de la tige. Ces sortes de crochets se soudent en quelque sorte avec le fond sur lequel ils reposent et il faut les briser pour les détacher. Par conséquent les *Pentacrinus Wyville-Thompsoni* (*sic*), que l'on a recontrés libres, avaient dû être arrachés à la suite de quelque accident du fond sur lequel ils vivaient, car il paraît bien difficile d'admettre que les mêmes animaux en des points divers de l'océan aient des modes d'existence differents."

The observations here recorded are undoubtedly of great value; but the conclusions drawn from them by Filhol appear to me to be somewhat rash. The "Talisman" specimens of *Pentacrinus wyville-thomsoni* seem to have been living on a stony or rocky bottom; and in fact Prof. Perrier[1] records that "plusieurs ont été ramenées avec les cailloux sur lesquels ils sont fixés." There can be no question therefore that *Pentacrinus wyville-thomsoni* lives in a permanently fixed condition on a hard bottom. But the "accident" which is supposed by Filhol to have liberated some fifteen fixed individuals must have been of a rather extensive character; and it must further have taken place at a sufficiently long time before they were dredged by the "Porcupine" for the lowest nodal joint of one of them to have lost its natural appearance (Pl. XXII. fig. 20) and have become enlarged and rounded as shown on Pl. XXII. fig. 27. But in other specimens the lowest nodal joint is far less modified. It retains its pentagonal shape and the thickened rim of the syzygial face, in the centre of which there is a small rounded tubercle covering the opening of the central canal. If all these specimens had been detached by one general "accident" anterior to the arrival of the "Porcupine's" dredge and tangles among them, their lowest nodal joints should have been in the same condition and not in different stages of modification. The same "accident" must have happened to the *Pentacrinus decorus* of the Caribbean Sea and to the *Pentacrinus maclearanus* of the Challenger dredgings, both of which were described by Sir Wyville as having the stems closed up at a modified nodal joint; but Filhol makes no reference whatever to these two types. He does not appear to dispute the fact that the "Porcupine" individuals of *Pentacrinus wyville-thomsoni* were free when captured; but he regards the observations of the "Talisman" as proving that this condition was not a natural one. Sir Wyville[2] believed that although the *Pentacrinus*, like the young *Comatula*, "was doubtless attached in its early days, it appears to have finally parted from its attachment, and to have led a free life;" and he pointed out that the syzygial union of the stem-joints at the nodes facilitated the rupture of the stem, just as is the case with the syzygies in the arms. His

[1] L'Expédition du Talisman, *Revue Scientifique*, No. 24, December 15, 1883, p. 741.

[2] Sea Lilies, *The Intellectual Observer*, August 1864, p. 7.

theory accounts for the varying conditions of the lowest nodal joint which are presented by different individuals; while the "accident" hypothesis of Filhol's does not explain this fact at all, unless he means that some individuals had become detached at one time and some at another. But this is precisely what Sir Wyville believed; only he regarded it as a natural event corresponding to the separation of the centro-dorsal of a *Comatula* from the rest of the stem below it, which appears to me to be a more rational explanation of the facts than that suggested by Filhol.

It is possible that the "accident" referred to by the latter author may not mean the fracture of the stem at a syzygy beneath a nodal joint as I have supposed above, but a separation of the stem from its anchorage by the lowest whorl of cirri. This would account for the modification of the nodal joint in the "Porcupine" specimens; for in the figure which Filhol gives to illustrate the mode of attachment of those dredged by the "Talisman," the lowest nodal joint is represented as not in contact with the rock beneath, to which its cirri are soldered; so that it might very well have been thickened and rounded in the manner described above. But this supposition, while removing one difficulty, only introduces another. The "Porcupine" specimens were living on a bottom of ooze at a depth of 1095 fathoms, considerably greater than the 1500 metres (800 fathoms) at which the "Talisman" examples were discovered on a rocky or stony bottom. Now in the first place, the cirri could not solder themselves to this ooze with such firmness that they would break rather than loose their hold; and secondly, there is no trace of such a connection in the cirri borne by the modified lowest nodal joint of any of the "Porcupine" specimens. For in some individuals (Pl. XIX. fig. 1) they are as perfect as those at the nodes above them, and not broken as they were in the detached specimens dredged by the "Talisman." In the case of *Rhizocrinus*, however, the attachment of the radicular cirri to stones and shells by slight calcareous expansions is well known (Pl. X. fig. 15).

All the Challenger Pentacrinidæ, with one exception, were dredged from mud or ooze, and though the stems of several of them terminate below in a rounded nodal joint as in the "Porcupine" examples of *Pentacrinus wyville-thomsoni*, I have seen no traces of their being attached by the cirri of the lowest whorl soldering themselves to the bottom, as described by the French zoologists.

The condition of four species of *Pentacrinus* which I have carefully examined with reference to this point appears to me to show conclusively that these observations have by no means the general application which is claimed for them. The internodes of *Pentacrinus wyville-thomsoni* are very long, while the cirri are short (Pl. XIX. fig. 1), so that only those of the lowest whorl can come in contact with anything beneath the lowest nodal joint. But the case is far different in many other species, among which I select four for special consideration, as they are represented by individuals in which the lowest whorls of cirri are better preserved than usual. In the present condition of many of the specimens several of the cirri on the stem are more or less broken; and though in the

case of the lowest whorls this may be due to the cirri having been soldered to the bottom by calcareous expansions, I have never seen any traces of such a condition.

In the first place, there is a stem-fragment of *Pentacrinus asterius*, consisting of a few internodal joints with a nodal joint beneath them which is somewhat worn and has its central canal closed up by a low rounded tubercle; so that it must have been detached for some time from the infra-nodal joint which completed the syzygy. But all the cirri borne by this modified nodal joint are perfect throughout their whole length, nearly 70 mm., and were most certainly not soldered to the bottom at the time the animal was captured.

Then again, in a fine *Pentacrinus müller*i from Martinique with a stem 120 mm. long, which is closed below at the thirteenth node, all the cirri of this node are perfect from the base to the terminal claw. They reach 50 mm. in length, and are spread out in different directions, two being curved sharply upwards, while the others are more or less horizontal. Their general appearance is very similar to that of the long cirri of *Antedon phalangium*. But not one of them shows any trace of having been soldered to the bottom. The cirri of the next four whorls above are all long enough to have touched the bottom had the animal been attached like the individuals of *Pentacrinus wyville-thomsoni* dredged by the "Talisman." Eight of these twenty cirri, four in the first whorl, two in the next, and two in the highest one, are now more or less broken; but this is clearly due to accident, and not to the fracture of an attachment. The same may be said of a specimen of *Pentacrinus müller*i in the Natural History Museum, which has a stem 135 mm. long, with several of the lower cirri remaining unbroken; while the under surface of the twelfth nodal joint at which the stem ends is worn and somewhat rounded, and bears two or three attached Foraminifera. The animal cannot, therefore, have been attached by the base of the stem, though the cirri may have been soldered to the bottom; but their appearance is against this supposition.

The same remarks apply to *Pentacrinus alternicirrus*, in which the cirri reach 50 mm. in length. Those of the four or five lowest whorls turn more or less directly downwards, and all reach below the level of the terminal nodal joint, which may be anywhere between 47 and 155 mm. from the calyx. But none of these cirri in any of the twelve individuals which I have examined show any signs of having been soldered to the bottom. Many of them are now broken; but others are quite perfect, though they must have been in contact with the bottom, had the animals been permanently anchored like the "Talisman" examples of *Pentacrinus wyville-thomsoni*. The single *Pentacrinus* dredged by the Challenger on hard ground belonged to this species; and as all the cirri of the lowest whorls are more or less broken, it is quite possible that they may have been torn away from a permanent attachment to the bottom. Another conclusive argument against the general application of the "Talisman" observations is afforded by the condition of the single specimen of *Pentacrinus maclearanus* which was dredged by the Challenger from a

bottom of red mud (Pl. XVI. fig. 1). The cirri, though short, are very closely set, and those of the five lowest whorls bend downwards underneath the last nodal joint and interlace with one another so as to form a kind of basket-work just like that beneath the centrodorsal of a *Comatula* with many cirri, such as *Antedon eschrichti*. This led Sir Wyville Thomson[1] to remark that "from the attitude of the cirri and from the appearance of the end of the stem there can be no doubt that this specimen is complete, that it is mature, and that it was living in an unattached condition." I do not well see how this statement can be disputed. Neither do I understand the difficulty of admitting that the mode of life of a *Pentacrinus* may vary in different localities. The Comatulæ are fixed when young, and semi-free when mature, attaching themselves by their cirri to various objects; but some species (*Actinometra jukesi* and *Actinometra stellata*, &c.) eventually lose their cirri altogether, and must then live an absolutely free life. The Palæozoic *Agassizocrinus* and *Edriocrinus* were attached when young, but subsequently became perfectly free. Considering that these great changes take place during the life of a single individual, I fail to see the difficulty of admitting that a particular species of *Pentacrinus* can adapt itself to the conditions of its existence, some young individuals fixing themselves permanently when they have the opportunity; while others living on soft ooze in deeper water separate themselves from their original anchorage and lead a partially free existence, being only attached temporarily, just as a *Comatula* is. A precisely similar case to that of *Pentacrinus wyville-thomsoni* is presented by *Pentacrinus decorus*. Some individuals are firmly fixed to telegraph cables by the spreading base of their stem, while others have been found in the semi-free condition.

Circumstances alter cases; and the question of the natural freedom of the individual represented in Pl. XIX. fig. 1, which has five perfect cirri on a rounded nodal joint at the base of the stem, is by no means negatived, because the "Talisman" found several others attached by calcareous growths round the cirri of the lowest whorl. The French zoologists, however, appear to consider that this observation proves Sir Wyville to have been wrong; whereas, on the contrary, the dredgings of the Challenger and the "Blake" have confirmed his views in the most satisfactory manner.[2]

Except at the lowest nodal joint the cirri of *Pentacrinus wyville-thomsoni* appear to be usually directed upwards (Pl. XVIII. figs. 1, 3; Pl. XIX. fig. 1); and the supra-nodal joint is accordingly slightly grooved for the reception of the cirrus-bases (Pl. XIX. figs. 3, 4; Pl. XXII. fig. 17) instead of the infra-nodal joint as is so markedly the case in *Pentacrinus blakei* and *Pentacrinus decorus* (Pl. XXXI. figs. 1, 3; Pl. XXXIV. fig. 1; Pl. XXXVI.), in which the cirri are usually directed downwards. In this respect, therefore, *Pentacrinus wyville-thomsoni* presents an approach to the genus *Metacrinus*, in

[1] The Atlantic, vol. ii. p. 126.

[2] Much of what has been written above would have appeared more suitably in Chapter II. pp. 18–22, where the mode of life of the Pentacrinidæ is discussed. But as Filhol's article did not appear till after this chapter had gone to the printers, and did not come under my notice till five months later, I have been obliged to take up the subject again.

which the upward direction of the cirri and the grooving of the supra-nodal joint are tolerably constant characters (Pl. XXXVIII.; Pl. XXXIX. figs. 3, 9; Pls. XL., XLII., XLV.; Pl. XLVII. figs. 1, 2; Pl. XLVIII.).

Another small point of resemblance between the European *Pentacrinus* and the Pacific *Metacrinus* is the slight tendency sometimes shown by the basals of the former to send median downward extensions over the interradial ridges at the top of the stem (Pl. XVIII. fig. 2), for this character is very generally distinctive of *Metacrinus* (Pl. XXXIX. fig. 1; Pl. XLIII. figs. 1, 3; Pl. XLVIII.). The basals of *Pentacrinus wyville-thomsoni* are almost always markedly pentagonal, the height being decidedly greater in the middle than at the sides, where, however, it is usually distinctly appreciable (Pl. XVIII. fig. 3; Pl. XIX. figs. 1, 6, 7; Pl. XX. fig. 3). Sometimes, however, they become almost triangular in outline (Pl. XVIII. figs. 1, 2), and one or more of them occasionally fail to meet their fellows, a variation which is more frequently met with in *Pentacrinus mülleri* (Pl. XV. figs. 1, 2) and *Pentacrinus naresianus* (Pls. XXVIII., XXIX.).

The number of arms in *Pentacrinus wyville-thomsoni* is comparatively small, being sometimes as low as fourteen; for two or even three of the rays may have no axillary but the third radial, as is sometimes the case in *Pentacrinus decorus* (Pl. XXXV.); and the distichal axillaries, when present, rarely occur all round the cup (Pl. XVIII. fig. 3). The examples figured in Pl. XVIII. figs. 1, 2, and Pl. XIX. figs. 1, 6, 7, are some of those with the greatest number of arms, a tertiary (palmar) axillary being occasionally present beyond the distichal; but I do not know of any specimen in which the number of arms exceeds twenty-two.

The disk (Pl. XVII. fig. 6) is closely covered by a pavement of anambulacral plates, several of which are pierced by water-pores. These are almost entirely absent in the anal interradius, in the proximal part of which the plates are closer set than usual, and arranged into two lateral groups. At first sight these look like large single plates, and are suggestive of orals, but they become resolved on further examination into small and very closely set plates. The ambulacra of the disk are protected by irregular plates which cover them in completely in the dry state. They are more regularly arranged on the arms, but are discontinuous on alternate sides between the pinnule-bases (Pl. XVII. fig. 4); and the perisome covering the muscular bundles is likewise plated, as in the allied *Pentacrinus alternicirrus* (Pl. XXVII. fig. 6). The covering plates of the pinnule-ambulacra are not very distinctly marked off from the lateral calcareous band, especially at the bases of the pinnules; and this band itself is but very imperfectly differentiated into side plates (Pl. XVII. figs. 2, 3).

Unlike many of the Pacific Pentacrinidæ, which were white when fresh, living examples of *Pentacrinus wyville-thomsoni* have a beautiful grass-green colour. This becomes duller in spirit, which acquires a purplish-red tinge. Prof. Moseley kindly

examined some of it with the spectroscope, and found the usual bands of pentacrinin. A few specimens which have not been kept in the dark, but have been more or less exposed to light, have bleached completely white.

5. *Pentacrinus alternicirrus*, n. sp. (Pls. XXV., XXVI.; Pl. XXVII. figs. 1–10).

Dimensions.

Total length,	195 mm.
Longest stem, rounded off at sixteenth node,	113 „
Shortest stem, rounded off at eleventh node,	47 „
Diameter of stem,	5 „
Longest cirrus (thirty joints),	52 „
Diameter of calyx,	9 „
Diameter of disk,	14 „
Length of arm (eighty joints),	100 „
Length of pinnule on first free brachial (eleven joints),	10 „
Length of pinnule from middle of arm (twenty-one joints),	21 „

Stem smooth, short, and pentagonal, with rounded angles. Four to nine (usually five or six) internodal joints with crenulated edges. The nodal joints bear two and three cirri alternately, those at one node corresponding to the positions of the absent cirri at the nodes next above and below. Cirrus-sockets nearly circular, occupying the whole height of the nodal joint, and extending upwards on to the supra-nodals. Infra-nodals scarcely modified at all. The sockets are deeply hollowed and have prominent lateral rims, owing to the angles of the joint between them being produced outwards and rounded. Cirri composed of about thirty stout joints, the lowest of which, after the first four, are somewhat longer than their successors. The terminal claw is moderately large, and has no opposing spine, but the ventral surface of the later joints is a little uneven. The lowest limit of the interarticular pores is between the fifth and eighth nodes.

Basals rhomboidal, extended slightly downwards, and produced laterally so as to meet their fellows in the re-entering angles of the calyx. The rays and their subdivisions in close lateral contact; the joints as far as the sixth or eighth brachial having flattened sides. The two outer radials united by syzygy. About thirty (twenty-five to thirty-two) arms, usually six to each ray, the axillaries being limited to the outer divisions. Primary, secondary, and tertiary arms (the latter very rare) each of two joints united by syzygy. The two lowest brachials united in the same way, the epizygal bearing the first pinnule. Arms of about eighty smooth, oblong joints with syzygies at intervals of three to eight (usually five or six) joints. The first one between the ninth and twenty-sixth brachials. First pinnules quite short, consisting only of ten or eleven joints, the lowest of which are broad and flat, and the later ones long and slender. This inequality gradually disappears as the pinnules increase in length towards the middle of the arm, where they are tapering

and styliform, consisting of about twenty smooth, flattened joints with sharp dorsal edges. The disk is completely covered with a pavement of small plates, as is the brachial perisome above the muscular bundles. Arm-groove moderately wide, and bordered by a discontinuous series of ambulacral plates. The pinnule-ambulacra have covering plates, and sometimes moderately distinct side plates.

Colour in spirit, yellowish-white, sometimes retaining a rosy tinge.

Localities.—Station 171, July 15, 1874; near the Kermadec Islands; lat. 28° 33′ S., long. 177° 50′ W.; 600 fathoms; hard ground; bottom temperature, 39°·5 F. One specimen.

Station 214, February 10, 1875; off the Meangis Islands; lat. 4° 33′ N., long. 127° 6′ E.; 500 fathoms; blue mud; bottom temperature, 41°·8 F. Several specimens.

Uncertain—Station 210, January 25, 1875; off the Panglao and Siquijor Islands; lat. 9° 26′ N., long. 123° 45′ E.; 375 fathoms; blue mud; bottom temperature, 54°·1 F.

Some of the fifteen specimens sent to me were without labels; and I strongly suspect that this species, together with *Pentacrinus naresianus*, three examples of which are without labels, are those referred to by Sir Wyville, who recorded in his journal that four specimens of two species of Pentacrinidæ were dredged at Station 210; for the collection contains no specimens at all with the label of this Station.

Remarks.—*Pentacrinus alternicirrus*, like *Pentacrinus wyville-thomsoni*, appears to be pre-eminently one of those which lives in a semi-free condition, the stem having been broken at a nodal joint, the syzygial face of which becomes worn and more or less rounded, and has its central canal closed up. The following list shows the position of this terminal nodal joint and the corresponding length of the stem in twelve specimens.

Stem, 47 mm.	long	and terminating at the	11th node.
„ 49	„	„	11th „
„ 63	„	„	11th „
„ 64	„	„	11th „
„ 65	„	„	11th „
„ 55	„	„	12th „
„ 66	„	„	12th „
„ 69	„	„	12th „
„ 70	„	„	12th „
„ 65	„	„	14th „
„ 91	„	„	14th „
„ 113	„	„	16th „

The remarkable arrangement of the cirri in this species distinguishes it at once from all the other recent Pentacrinidæ. Except that the symmetry is pentamerous instead of tetramerous, the arrangement recalls that of the leaves on the stem of a Labiate plant. In one case only have I found any irregularity. The eighth whorl has its two regular cirri like the sixth, together with an additional one which therefore comes to be on the

same side of the stem as the third cirrus in the seventh whorl. But the ninth whorl has only two cirri instead of three, and is the beginning of a new cycle; for the tenth whorl is not like the sixth with only two cirri, but resembles the irregular eighth one with three. In the same way the eleventh whorl is like the ninth and not the seventh, and so on.

The absence of cirri at some of the nodes of *Pentacrinus alternicirrus* is the more striking as there are regularly five cirri at each node in all the Pentacrinidæ, both recent and fossil, with three exceptions. These are *Pentacrinus bronnii*, Hagenow,[1] from the White Chalk of Rügen, and *Pentacrinus didactylus*, d'Orbigny,[2] from the Eocene of Biarritz, both of which have only two cirri at a node; while under the name of *Pentacrinus tridactylus*, Quenstedt[3] has described another Tertiary stem-fragment from Le Vit in the south of France, which has a verticil of three cirri only. It is just possible that if longer pieces of these stems were known they might show the same regular alternation in the positions of the successive cirrus-whorls which is so striking in *Pentacrinus alternicirrus*. But whether this be the case or not, the departure from the pentamerous arrangement of cirri which is so characteristic of the Pentacrinidæ is not a little remarkable. For verticils of two cirri alternating with one another in position sometimes occur in both *Bourgueticrinus* and *Mesocrinus*; though the structure of the stem in these genera is totally different from that of *Pentacrinus*, as has been fully explained in Chapter II.

In consequence of the absence of two or three cirrus-sockets, the nodal joints of *Pentacrinus alternicirrus* depart considerably from the symmetrical form presented by those of other Pentacrinidæ, as is shown in Pl. XXVI. figs. 13, 14, and Pl. XXVII. figs. 2, 3. The last two represent syzygial faces of two successive nodes in their relative positions, the two empty sides in fig. 2 being occupied by sockets in fig. 3.

Apart from the arrangement of the cirri, *Pentacrinus alternicirrus* resembles *Pentacrinus maclearanus* and *Pentacrinus mülleri* in the shortness of the internodes, while it agrees with both these species and also with *Pentacrinus wyville-thomsoni* in the regularity and the grouping of the arm-divisions. The general arrangement of the crown of arms (Pl. XXV.) is most like that of *Pentacrinus wyville-thomsoni* (Pl. XIX. fig. 1); and the long middle pinnules of the two species are very similar, while the characters of the perisomatic skeleton are almost identical (compare Pl. XVII. figs. 2–4, and Pl. XXVII. figs. 4–6).

The leading characters of *Pentacrinus alternicirrus* appear to be very constant, the South Pacific specimen from near the Kermadecs being in no way distinguishable from those dredged off the Meangis Islands. This is a striking contrast to the variations of

[1] Monographie der Rügenschen Kreide-Versteinerungen, *Neues Jahrb. f. Mineralogie*, Jahrg. 1840, p. 663, Taf. ix. fig. 9.

[2] See d'Archiac, Description des fossiles recueillis par M. Therent, dans les couches à nummulines des environ de Bayonne, *Mém. Soc. géol. de France*, 2me sér., t. ii. 1re partie, 1846, p. 200, pl. v. figs. 16*a*, 17*a*.

[3] Encriniden, p. 268, Tab. 99, fig. 170.

Pentacrinus decorus and *Pentacrinus mülleri* in the Caribbean Sea. There are nearly always five or six internodal joints in the stem, and I have only noticed two cases of an arm-division consisting of more than two joints united by syzygy. One has three joints, of which the first two form a syzygy, and in the other there are four, those of each pair being united by syzygy. In the arms, however, the position of the syzygies, after that at the base, is exceedingly variable. But this is always the case in the few species of *Pentacrinus* which have syzygies in the arms, the contrast between them and the Comatulæ being very striking in this respect.

Pentacrinus alternicirrus appears to inhabit moderately deep water, the depths at the two Stations from which it is recorded being respectively 500 and 600 fathoms; while at the doubtful Station 210 the depth was 375 fathoms. Five of the individuals dredged at Station 214 (Meangis Islands) were infested with encysted Myzostomas, as were also many of the Comatulæ. In one specimen no less than eight arms bore more or less perfect cysts of *Myzostoma pentacrini*, von Graff, two of them having two cysts a short distance apart. In other cases the cysts were principally formed in the skeleton of the pinnules by *Myzostoma deformator*, von Graff,[1] as shown in Pl. XXVII. figs. 7 and 8; while figs. 9 and 10 represent cysts formed in the substance of the arm.

6. *Pentacrinus naresianus*, n. sp. (Pl. XXVII. figs. 11–13; Pls. XXVIII.–XXX.).

Dimensions.

Total length of largest specimen, stem broken at thirtieth node,	54·00 cm.
Length of this stem,	38·00 „
Diameter of stem,	5·00 mm.
Longest cirrus (thirty-five joints),	25·00 „
Diameter of calyx,	7·75 „
Length of arm (eighty joints),	150·00 „
Length of first pinnule (twelve joints),	8·50 „
Length of pinnule from middle of arm (twenty-two joints),	24·00 „

Stem long and smooth, of a rounded pentagonal or circular form. Eight to eighteen (usually about ten or twelve) internodal joints with but slightly crenulated edges. Nodal joints high, not projecting outwards at the angles, but deeply hollowed by the cirrus-sockets, which have nearly circular facets and terminate far below the upper edges of the nodal joints. Infra-nodals deeply grooved to receive the cirrus-bases, so that the sockets appear to have pyriform downward extensions. Cirri moderately slender, of thirty to thirty-five tolerably uniform joints, all but the lowest of which have one or two blunt projections on the dorsal edge. Lowest limit of the interarticular pores between the fifth and eighth nodes.

Basals small, triangular or pentagonal, sometimes meeting laterally and sometimes

[1] Zool. Chall. Exp., part xxvii. pp. 62–66, 1884.

not, owing to the radials being prolonged slightly downwards over the upper stem-joints. Ten arms only, but the rays are in close lateral contact, the second radials being united all round, while the axillaries and the first two brachials have flattened outer sides. Second and third radials and the first two brachials respectively united by bifascial articulation. Arms of about ninety joints,[1] the lower ones bluntly wedge-shaped and the later joints nearly oblong or squarish, with raised distal edges so as to overlap slightly. A syzygy in the third brachial, another between the sixth and fifteenth joints, and others at intervals of four to twelve (usually seven to nine) joints. The proximal face of the epizygal forms a sharp angle projecting backwards into the retreating distal face of the hypozygal, the dorsal surface of which projects forwards into that of the epizygal. The first pinnules are quite short, consisting only of about twelve joints, the lowest half of which are broad and flattened and the later ones quite small. This inequality gradually disappears as the pinnules increase in length, the lower joints becoming less broad and the later ones more elongated. Those on the middle of the arm are long and styliform, consisting of about twenty joints, the first of which are much broader than the rest.

Disk covered with numerous, closely set, irregular plates. These extend on to the arms at the sides of the ambulacra, which are altogether above the arm-groove, and are protected by a continuous series of tolerably regular covering plates. There are no definite side plates on the pinnules, but only a narrow band of limestone with its edges cut into teeth which bear the covering plates.

Colour in spirit, pinkish-white.

Localities.—Station 170, July 14, 1874; near the Kermadec Islands; lat. 29° 55′ S., long. 178° 14′ W.; 520 fathoms; volcanic mud; bottom temperature, 43° F. Two quite young specimens.

Station 170A, July 14, 1874; near the Kermadec Islands; lat. 29° 45′ S., long. 178° 11′ W.; 630 fathoms; volcanic mud; bottom temperature, 39°·5 F. A stem-fragment only.

Station 171, July 15, 1874; near the Kermadec Islands; lat. 28° 33′ S., long. 177° 50′ W.; 600 fathoms; hard ground; bottom temperature, 39°·5 F. A stem-fragment and some broken arms.

Station 175, August 12, 1874; near Fiji; lat. 19° 2′ S., long. 177° 10′ E.; 1350 fathoms; Globigerina ooze; bottom temperature, 36° F. A calyx with a fragment of a stem.

Station 214, February 10, 1875; off the Meangis Islands; lat. 4° 33′ N., long. 127° 6′ E.; 500 fathoms; blue mud; bottom temperature, 41°·8 F. Six specimens.

Uncertain—Station 210, January 25, 1875; off the Panglao and Siquijor Islands; lat. 9° 26′ N., long. 123° 45′ E.; 375 fathoms; blue mud; bottom temperature, 54°·1 F.

Three specimens reached me without any labels. Some or all of them were probably

[1] I have seen no arm with more than eighty joints; but the extremities of the arms are broken in all the specimens.

obtained at Station 210, where four individuals of two species of *Pentacrinus* were dredged (see p. 128); but, as in the case of *Pentacrinus alternicirrus*, I can only infer this from the fact that these two species, together with the single specimen of *Metacrinus murrayi*, were the only ones which came into my hands without any record of locality; while there were none with the label of Station 210.

Remarks.—*Pentacrinus naresianus* is remarkable as being the only recent species of the genus in which there are not more than ten arms; while the shape of the arm-joints, especially the lower ones (Pl. XXVIII. fig. 1; Pl. XXIX; Pl. XXX. fig. 1), is also more oblique than is usually the case in the Pentacrinidæ, so that in both respects it approaches the Comatulæ. Apart from these characters and the well plated ambulacra (Pl. XXVII. fig. 13), the arms are readily distinguished by the peculiar form of the syzygial unions. When seen from the dorsal side (Pl. XXIX. fig. 1; Pl. XXX. fig. 1), the distal edge of the hypozygal appears to be very convex and to project strongly forwards into the epizygal; while in a side view (Pl. XXX. fig. 23) the epizygal shows a sharp backward projection into the hypozygal. When the syzygial faces are exposed (Pl. XXX. figs. 20, 21), a sharp angle appears across the middle of the proximal face of the epizygal; and the distal face of the hypozygal has a corresponding re-entering angle, so that the two joints interlock very closely. Essentially the same form of syzygy recurs in *Pentacrinus blakei* of the Caribbean Sea (Pl. XXXII. figs. 5, 7, 12, 14); but the other characters of this species are entirely different from those of *Pentacrinus naresianus*, as it has twenty to thirty arms and a more slender stem with shorter internodes (Pl. XXXI.).

These two species, together with *Pentacrinus decorus*, are the only three recent Pentacrinidæ in which the two outer radials and the two first joints beyond them are united by bifascial articulation. The articular faces of these joints in *Pentacrinus naresianus* are shown in Pl. XXX. figs. 11, 12, 16, 17. It further resembles *Pentacrinus decorus* in the pyriform downward prolongation of the cirrus-sockets over the infra-nodal joints, the upper faces of which are markedly stellate in consequence (Pl. XXX. fig. 29). The nodal joints, however, are not produced outwards at the angles between the cirrus-sockets, nor do they slope outwards from their upper edge to the top of the sockets; so that the general outline of the stem is very even (Pl. XXVIII. fig. 2). But in *Pentacrinus decorus* this enlargement of the nodal joints is very perceptible in mature individuals (Pl. XXXVI.; Pl. XXXVII. figs. 1, 2), though not in the youngest (Pl. XXXV.). On the other hand, it appears in the youngest specimens of *Pentacrinus naresianus* (Pl. XXXa. fig. 5), though disappearing some time before maturity is reached.

Pentacrinus naresianus also presents a considerable variation in the size and shape of the basals, which is so very remarkable a character of *Pentacrinus decorus*. In all the four figures of the calyx which were drawn for Sir Wyville Thomson (Pls. XXVIII.–XXX.), the basals are represented as separated by small downward extensions of the

radials; but this is not quite the case in the original of fig. 2 on Pl. XXIX., for the basals form a compact ring entirely separating the radials from the top of the stem. In other specimens, again, some of the basals meet their fellows, while the remainder are more or less completely separated by the downward extending radials.

Pentacrinus naresianus does not appear to be one of those which live in a semi-free condition like the three last described, while the stem grows to a greater length than in most of these forms. It is broken below in all the specimens obtained, and though this has sometimes taken place at a node, the fracture is evidently a recent one, the syzygial surface not being worn and more or less rounded, as in *Pentacrinus wyville-thomsoni* and the other semi-free types.

The young individuals of *Pentacrinus naresianus*, besides exhibiting the usual characters common to all young Pentacrinidæ (*ante*, pp. 289–291), have one or two peculiarities of their own. The second radials are less closely united, only meeting one another for half the length of their sides (Pl. XXXa. fig. 1); while the sides of the axillaries and of the two following joints are not so much flattened as in the adult, but the edges where the ventral and dorsal surfaces meet are sharp and straight.

The characters of the arm-syzygies are also slightly different from those which appear in the adult. The backward projection of the epizygal is much nearer the edge of the joint than in the adult arm, in which the crest of the ridge on the syzygial face crosses the axial canal. This gives an entirely different appearance to the joints when seen in profile, as will be evident upon a comparison of figs. 9–12 on Pl. XXXa., which represent a young and an old syzygial pair, as seen from the side and from above respectively.

The difference in the sculpture on the young and on the older stem-joints is also shown in Pl. XXXa. figs. 2, 3, 7. In the young individual figured on the same plate the head is but 55 mm. long, and there are only about fifty joints in the arms. The diameter of the stem is 2 mm. Its internodes are exceptionally long, seventeen or eighteen joints; and there are only two cirri at one of the nodes (the fifth),[1] just as is apparently the case through the whole stem of *Pentacrinus didactylus*.

Two stem-fragments from this Station (170), one of which (and possibly both) belong to this same individual, exhibit some remarkable peculiarities of growth. In the upper one (Pl. XXXa. fig. 5) two of the nodal joints are slightly enlarged as described above. But seven joints lower down a kind of calcareous sheath appears on the outside of the stem, which is segmented in the same way as the stem, and is continued downwards over the next node. This is of an altogether abnormal character. The outer crust shows various irregular lines, and seems to have filled up the downward extensions of the cirrus-sockets on to the infra-nodal joints, so that no trace of them is visible.

[1] The absent cirri at this node were erroneously inserted by the artist, when restoring the broken ones elsewhere; and I did not notice the fact till it was unfortunately too late to remedy it.

This condition recurs over a length of three internodes on the remaining stem-fragment, the sockets gradually becoming more and more obscured; and at the lowest node the incrustation seems to have completely overgrown the bases of the cirri, nothing appearing to indicate their presence but minute irregular stumps. Fifty joints lower down the stem terminates in a flattened expansion by which it was probably attached. The abnormal condition of this stem is interesting from its resemblance to that presented by a specimen of the fossil *Millericrinus pratti*, which I have described elsewhere.[2] In this case, however, the secondary deposit of limestone which is outside the uppermost stem-joints is divided up into segments not corresponding with those enclosed by it.

7. *Pentacrinus blakei*, P. H. Carpenter (Pls. XXXI., XXXII.; Pl. XXXIII. figs. 1–3).

1882. *Pentacrinus blakei*, P. H. Carpenter, Bull Mus. Comp. Zoöl., vol. x. p. 172.

Dimensions.

Total length,	27·5 cm.
Longest stem, rounded off at twenty-fourth node,	160·0 mm.
Diameter of stem,	4·0 „
Longest cirrus (twenty-nine joints),	17·0 „
Diameter of calyx,	6·0 „
Length of arm (one hundred and five joints),	120·0 „
Length of pinnule on first distichal (eighteen joints),	9·0 „
Length of pinnule from middle of arm (twenty joints),	12·0 „

Stem slender and smooth, with a rounded pentagonal outline; five to seven internodal joints with distinctly crenulated edges. Nodal joints high, not projecting outwards between the cirrus-facets, which are comparatively small and circular, and do not nearly reach their upper edge. Infra-nodals more or less grooved to receive the cirrus-bases, so that the sockets appear to have pyriform downward extensions of variable size. Cirri small and slender, of twenty-five to thirty joints, the first six of which are quite short, and the remainder squarish with a tolerably smooth dorsal edge. Terminal claw small, with no opposing spine. Lowest limit of the interarticular pores between the sixth and tenth nodes.

Basals small, triangular, and more or less rounded, well separated laterally by the lowest parts of the rather high radials. The rays and their subdivisions moderately close, without any intervening perisome, but scarcely flattened at all except just on the lower brachials. The two outer radials and lowest distichals respectively united by bifascial articulation. The third radials and the second distichals project backwards into the middle of the preceding joints, their proximal surfaces being somewhat deeply hollowed from side to side, and slanting downwards and backwards. About twenty arms, usually only

[1] *Quart. Journ. Geol. Soc.*, vol. xxxviii. p. 33, pl. i. fig. 21.

four, but occasionally three or five to each ray. Primary arms of one to four distichal joints, of which the first two are united by a ligamentous articulation. The second one bears a pinnule, and the next may be either a simple axillary or consist of two syzygial joints. Secondary arms (rare) of two palmar joints united by syzygy. Arms of about ninety slightly overlapping joints, nearly oblong at first, but afterwards becoming more unequal sided. The first free brachial bears a pinnule, and the second is usually a syzygial joint, while other syzygies occur on the arms at intervals of two to twenty joints. The proximal face of the epizygal forms a sharp angle which projects backwards into the retreating distal face of the hypozygal.

The lowest brachial pinnules consist of seventeen or eighteen joints, the first six of which are rather broad, and the later ones more slender. Farther out on the arm this inequality gradually disappears, all the joints but the first two being moderately long and narrow. The disk, so far as visible, is covered with small, closely set plates which extend on to the arms, covering the muscular bundles at the sides of the narrow arm-groove. The covering plates of the pinnule-ambulacra rest upon a denticulated band of limestone which is not fully differentiated into side plates.

Colour in spirit, yellowish-white.

Localities.—All in the Caribbean Sea. From the dredgings of the U.S. Coast Survey steamer "Blake." Cruise of 1878–79. No. 157, off Montserrat; 120 fathoms. No. 209, off Martinique; 189 fathoms; hard bottom; bottom temperature, 49$\frac{3}{4}$° F. No. 291, off Barbados; 200 fathoms; flat calcareous stones; bottom temperature, 49$\frac{3}{4}$° F. No. 295, off Barbados; 180 fathoms; hard bottom; bottom temperature, 50$\frac{3}{4}$° F.

Remarks.—This interesting species, like *Pentacrinus asterius*, appears to be somewhat rare, having only been dredged four times by the "Blake"; and it has never, so far as I know, been obtained by Mr. Damon's agents, as the other three West Indian species have been. I have only been able to examine a mutilated specimen from Montserrat, and three nearly perfect ones from Barbados.

The slender cirri and their close approximation on the stem give this type a more elegant appearance than *Pentacrinus decorus*, which is its nearest ally, these two being the only species with more than ten arms which have a bifascial articulation between the radials. The third species with this character (*Pentacrinus naresianus*) is only ten-armed; but it has a singular resemblance to *Pentacrinus blakei* in the form of the syzygies on the arms. The stem of *Pentacrinus blakei* is at once distinguished from that of *Pentacrinus decorus* by the shortness of the internodes and the absence of any enlargement at the nodes (Pl. XXXI. fig. 3). The cirrus-sockets, too, are generally prolonged downwards to a less extent than they are in *Pentacrinus decorus* (Pl. XXXVI.); though *Pentacrinus blakei* shows a considerable amount of variability in this respect, some sockets having almost no downward extensions at all, while others are more like those of *Pentacrinus decorus*. There is, however, remarkably little variation in the length of the

internodes, especially as compared with *Pentacrinus mülleri*, in which the stem reaches about the same length. There are also more arms in *Pentacrinus decorus* than in *Pentacrinus blakei*, in which palmar series are very rarely present, so that the total number of arms would not exceed twenty. But the great distinguishing character of *Pentacrinus blakei* is the nature of its bifascial articulations and syzygies. Seen from the dorsal side or in profile (Pl. XXXI. figs. 1, 2; Pl. XXXII. fig. 15), the third radial shows a strong backward projection into the second. But its proximal face not only is concave from side to side, but also slopes strongly downwards and backwards; and the upper ventral edge of the second radial is bent forward so as to fit into the gap thus formed (Pl. XXXII. fig. 18). There is a very slight indication of this in *Pentacrinus naresianus* (Pl. XXX. figs. 1, 11, 12); but the two species resemble one another much more closely in the curious angular form of the syzygial faces. Those of *Pentacrinus naresianus* (Pl. XXX. figs. 20, 21, 23) have been already described, and those of *Pentacrinus blakei* are shown in Pl. XXXII. Whether it be a brachial syzygy (figs. 4, 5, 7) or one in the distichal axillary (figs. 9, 12, 14) the form is just the same. The proximal face of the epizygal rises to a sharp crest, which is interrupted by the central canal, and fits into a corresponding re-entering angle on the distal face of the hypozygal, so that the muscle-plates of its proximal face are bent strongly forwards, just as they are in the bifascial articulation of the second radials with the axillaries (Pl. XXXII. figs. 15, 18). The general appearance of the syzygies in the side view of an arm is well shown in Pl. XXXIII. fig. 2, which should be compared with the corresponding figure of *Pentacrinus naresianus* (Pl. XXX. fig. 23). The flattened shape of the lower joints is also well shown in the former figure. Judging from the torn fragment of the disk which came away from this arm-base, we may suppose that its anambulacral plating was tolerably well developed. This plating extends out on to the arms, covering in the muscular bundles at the sides of the narrow arm-groove, though to a less extent than in the four preceding species. The pinnule-ambulacra (Pl. XXXIII. fig. 1) are much in the same condition as those of *Pentacrinus naresianus* (Pl. XXVII. fig. 11), the covering plates resting upon the toothed edge of a continuous calcareous band which is not perfectly differentiated into side plates.

. 8. *Pentacrinus decorus*, Wyville Thomson, 1864 (Pl. XXXIII. figs. 4–6; Pls. XXXIV.–XXXVII.; Pl. LVII. figs. 2–5; Pl. LVIII. figs. 1–3; Pl. LIX. figs. 1–4; Pl. LXII.).

1864. *Pentacrinus (Neocrinus) decorus*, Wyville Thomson, The Intellectual Observer, August 1864, p. 7.
1864. *Pentacrinus decorus*, Lütken, Vidensk. Meddel. f. d. nat. Foren. i Kjøbenhavn, 1864, Nr. 13–16, p. 208.
1865. *Pentacrinus (Neocrinus) decorus*, Wyville Thomson, Phil. Trans., 1865, vol. clv. p. 542.
1869. *Pentacrinus Mülleri*, Pourtalès, Bull. Mus. Comp. Zoöl., vol. i., No. 11, p. 357.
1872. *Pentacrinus Mülleri*, Wyville Thomson, Proc. Roy. Soc. Edin., vol. vii. p. 766; and The Depths of the Sea, p. 442.

1878. *Pentacrinus Müllerí*, Agassiz, Bull. Mus. Comp. Zoöl., vol. v., No. 6, p. 56.
1879. *Pentacrinus Müllerí*, Pourtalès, Bull. Mus. Comp. Zoöl., vol. v., No. 9, p. 214.
1879. *Pentacrinus Müllerí*, Agassiz, Bull. Mus. Comp. Zoöl., vol. v., No. 14, p. 296.
1882. *Pentacrinus decorus*, P. H. Carpenter, Bull. Mus. Comp. Zoöl., vol. x., No. 4, p. 171.

Dimensions.

Greatest length of stem, to fiftieth node,	80·00 cm.
Diameter of stem,	4·75 mm.
Longest cirrus (thirty-two joints),	27·00 „
Diameter of calyx,	8·00 „
Diameter of disk,	12·30 „
Length of arm (one hundred joints),	80·00 „
Length of distichal pinnule (thirteen joints),	13·00 „
Length of pinnule from lower third of arm (twenty joints),	16·00 „

Stem moderately slender and usually smooth, with a rounded pentagonal outline. Seven to sixteen (usually eleven or twelve) internodal joints, with much crenulated edges. Nodal joints somewhat enlarged, expanding from above downwards to the top of the cirrus-sockets. These are deeply hollowed, and have a pear-shaped form, being continued downwards as well marked grooves on to the infra-nodals. Cirri small and slender, rarely composed of more than thirty joints, the first six of which are quite short and the remainder squarish or slightly elongated, with a moderately smooth dorsal edge. Terminal claw small, with no opposing spine. Lowest limit of the interarticular pores between the ninth and eleventh nodes.

Basals very variable, sometimes quite small, inconspicuous, and isolated; but presenting all gradations from this condition up to that of large triangular knobs standing out prominently from the general plane of the calyx, and meeting one another by their extended lateral angles.

The two outer radials united by bifascial articulation. The rays and their subdivisions sometimes separated by plated perisome, and sometimes in close apposition; but the sides of the lower arm-joints are scarcely flattened at all. Ten to twenty-five arms. Primaries of two to seven distichal joints. When three or more distichals are present the first two are united by bifascial articulation, the second bearing a pinnule, while the third or sometimes the axillary is a syzygy. But if there be only two distichals, and the axillary be a syzygy, the first bears a pinnule and is united to the second by muscles. Lastly, if the axillary be not a syzygy, there is a bifascial articulation between it and the first distichal. Secondary arms (when present) of one to nine palmar joints, which vary in character as in the primary arms, though to an even greater extent. If the arms become free at the radial axillary the first syzygy is usually on the third brachial; but if the primary arms divide there is generally a syzygy in the second free brachial, though not unfrequently it occurs between the first and second. The

next syzygy is from the eighth to the thirtieth brachial, after which there is an interval of five to eleven joints between successive syzygies in the free arms. These consist of from ninety to one hundred slightly overlapping joints, nearly oblong in shape in the lower parts, but gradually becoming squarer, and finally elongated.

The first pinnule is on the first distichal, if it be united to the second by muscles. In other cases the second distichal bears the first pinnule; and the same is the case in the free arms. The lowest pinnules consist of about a dozen flattened joints, all of which except the first are longer than broad. They have sharp dorsal edges, and are much flattened laterally, especially those near the base of the pinnule, the terminal ones being more slender, so that the pinnule tapers considerably. Farther out on the arm the joints become more equal, the three lowest being the only ones that are much flattened, but the pinnules do not increase greatly in length.

The disk bears numerous plates of variable size, rather closely set, but not forming a perfectly continuous pavement; and several of them support small blunt spinelets. The ambulacra of the disk and arm-bases are protected by somewhat narrow and spine-like plates irregularly disposed. Arm-groove moderately wide and continuously plated. Pinnule-ambulacra variable, sometimes having moderately distinct side plates and sometimes hardly any trace of them.

Colour when fresh, white, purple, or yellow (Sigsbee), bleaching nearly white in spirit.

Localities.—Abundant in the Gulf Stream and in the Caribbean Sea, but not known elsewhere. A few specimens have been obtained by the collectors for Sir Rawson Rawson and Mr. Damon; also by W. Stimpson off Cuba, and by Captain E. Cole of the telegraph steamer "Investigator" at the following localities—south side of Porto Rico, 667 fathoms; off Saba Island, 320 fathoms (with *Pentacrinus asterius*); between Saba and Eustatius Islands, 531 fathoms (with *Pentacrinus mülleri*). But great numbers have been dredged by the surveying ships of the U.S. Coast Survey, as recorded in the following list:—

S.S. "Corwin," 1867. 1·6 miles from Chorrera, Cuba; 270 fathoms.

S.S. "Bibb," 1869. Off Double-headed Shot Keys; 315 and 471 (?) fathoms.

S.S. "Blake," Cruise of 1877–78. No. 21, off Bahia Honda; lat. 23° 2′ N., long. 83° 13′ W.; 287 fathoms. Off Havana (Sigsbee); 150 to 200 fathoms. No. 56, off Havana; lat. 22° 9′ 15″ N., long. 82° 21′ W.; 175 fathoms. No. 57, off Havana; lat. 22° 9′ N., long. 82° 21′ W.; 177 fathoms.

Cruise of 1878–79. No. 100, off Morro Light; 250 to 400 fathoms. No. 101, off Morro Light; 175 to 250 fathoms. Nos. 155 and 156, off Montserrat; 88 fathoms; bottom temperature, 69° F. No. 157, off Montserrat; 120 fathoms; bottom temperature, 69° F. No. 233, off St. Vincent; 174 fathoms; rocky bottom; bottom temperature, 49½°F. No. 269, off St. Vincent; 124 fathoms; bottom temperature, 57½° F. No. 296, off Barbados; 84 fathoms; bottom temperature, 61½° F. No. 298, off Barbados; 120 fathoms; bottom temperature, 61° F.

Cruise of 1879–80 (Bartlett). Off Santiago de Cuba. Off Kingston (Jamaica); 100 fathoms.

Captain Sigsbee[1] describes the specimens dredged by him in the following terms:—"Some of them came up on the tangles, some on the dredge. They were as brittle as

[1] *Bull. Mus. Comp. Zoöl.*, vol. v., No. 6, p. 60.

glass. The heads soon curled over and showed a decided disposition to drop off. At a haul made soon after we got more, and being afraid to put so many of them in the tank together I tried to delude the animals into the idea that they were in their native temperature by putting them into ice-water. This worked well, although some of them became exasperated, and shed some of their arms. They lived in the ice-water two hours, until I transferred them to the tank. They moved their arms one at a time. Some of the lilies were white, some purple, some yellow; the latter was the colour of the smaller and more delicate ones." Mr. Alexander Agassiz[1] records that "our collection of Pentacrini is quite extensive; we found them at Montserrat, St. Vincent, Grenada, Guadeloupe, and Barbados, in several places, in such numbers that on one occasion we brought up no less than one hundred and twenty-four at a single haul of the bar and the tangles. We must, of course, have swept over actual forests of Pentacrini crowded together, much as we find the fossil Pentacrini on slabs. I have nothing to add to the general description of their movements given by Captain Sigsbee, with the exception of their use of the cirri placed along the stem. These they move more rapidly than the arms, and use them as hooks to catch hold of neighbouring objects, and, on account of their sharp extremities, they are well adapted to retain their hold. The stem itself passes slowly from a rigid vertical attitude to a curved or even drooping position."

Although the dredgings of the "Blake" have shown that *Pentacrinus decorus* is extremely abundant in the neighbourhood of several of the West Indian Islands, it does not appear to have been discovered till a century after *Pentacrinus asterius*. Its distinctness from that type was first recognised by Mr. Damon of Weymouth, who procured an example of it from the seas of the Outer Antilles. Its occurrence was recorded by the late Sir Wyville Thomson in a popular article on Sea Lilies, which appeared in the Intellectual Observer for August 1864, but he published no further description of it before his death. When he first noted its discovery he seems to have been unacquainted with the description of *Pentacrinus mülleri* by Oersted, published six years previously; for he spoke of *Pentacrinus asterius* and *Pentacrinus decorus* as the only two known living species of Stalked Crinoids. But in the following year[2] he referred to *Pentacrinus mülleri* as well, Lütken's Memoir having appeared in the interval; so that he evidently regarded *Pentacrinus decorus* and *Pentacrinus mülleri* as distinct species.

Later on, however, as I have described above, he came to the conclusion that his *Pentacrinus decorus* was identical with Oersted's type,[3] and he seems to have held this view till his death. For he wrote "*Pentacrinus mülleri*, Oersted," on a copy of Pl. XXXIV. This represents a specimen which he had obtained from Sir Rawson Rawson, and it is totally different from *Pentacrinus mülleri*, as is evident from a glance at Lütken's

[1] *Bull. Mus. Comp. Zoöl.*, vol. v., No. 14, p. 296. [2] *Phil. Trans.*, vol. clv., 1865, p. 542.
[3] *Proc. Roy. Soc. Edin.*, vol. vii. p. 766; and The Depths of the Sea, p. 442.

figure of that type. But it corresponds in every respect with the two individuals in the national collection which Sir Wyville himself described in 1864 as *Pentacrinus* (*Neocrinus*) *decorus*. A large number of examples, obviously of the same type, were dredged by the "Blake"; and I have no hesitation in considering *Pentacrinus decorus* as a good species; though for reasons given above I do not regard it as a type of subgeneric value. In fact Sir Wyville himself seems to have recognised this subsequently; for while still confounding *Pentacrinus decorus* with *Pentacrinus mülleri*, he dropped the names *Cenocrinus* and *Neocrinus* altogether, and simply spoke of *Pentacrinus asterius* and *Pentacrinus mülleri*.

Pentacrinus decorus differs from *Pentacrinus blakei* and *Pentacrinus naresianus* in the flatness of the syzygial faces on the arm-joints (Pl. XXXVII. figs. 3, 4), both these species having strongly angular syzygial faces (Pl. XXXa. figs. 9, 10; Pl. XXXII. figs. 4, 5, 7, 9, 12, 14). *Pentacrinus naresianus* has only ten arms, while the primary arms of *Pentacrinus decorus*, like those of *Pentacrinus blakei*, may divide once or twice. The second division is, however, more common in *Pentacrinus decorus* than in *Pentacrinus blakei*, in which palmar series are rare (Pl. XXXI.); though distichals generally occur with considerable regularity all round the cup, which is by no means always the case in *Pentacrinus decorus* (Pls. XXXV., XXXVI.). The general characters of the pinnules and of their ambulacral plating are much the same in the two species; but the two sets of ambulacral plates are on the whole much better differentiated in *Pentacrinus blakei* than in *Pentacrinus decorus* (Pl. XXXIII. fig. 1; Pl. XXXVII. figs. 23, 24). In the latter species (Pl. XXXIII. fig. 4) the arm-groove itself is more completely covered in by the bases of the pinnule-ambulacra, which overlap one another alternately from opposite sides much more perfectly than in *Pentacrinus blakei* (Pl. XXXIII. fig. 3). But the perisome covering the muscular bundles in the intervals between the ventral edges of the arm-joints is not plated in *Pentacrinus decorus* (Pl. XXXIII. figs. 4, 6) as it is in *Pentacrinus blakei* (fig. 3), and also in some other Pentacrini previously described, together with some species of *Metacrinus*. But the chief and most obvious difference between *Pentacrinus decorus* and *Pentacrinus blakei*, apart from the peculiarities of the brachial syzygies in the latter species, lies in the characters of the stem. The internodes in most stems of *Pentacrinus decorus* are considerably longer than those of *Pentacrinus blakei*, as is evident upon comparison of Pls. XXXIV. and XXXVII. with Pl. XXXI.; and the nodal joints are markedly different in the two species. Those of *Pentacrinus decorus* are considerably enlarged above the deeply hollowed cirrus-sockets (Pl. XXXVI.), so that the outline of the stem is not uniform as it is in *Pentacrinus blakei* (Pl. XXXI. fig. 3); while the contour of the nodal joints as seen from beneath is less rounded in *Pentacrinus decorus* (Pl. XXXVII. fig. 21) than in *Pentacrinus blakei* (Pl. XXXII. fig. 1). The general appearance of the infra-nodal joints (Pl. XXXII. fig. 2; Pl. XXXVII. fig. 19) and also of the ordinary

joint-faces (Pl. XXXII. fig. 3; Pl. XXXVII. fig. 22) is, however, very much the same in the two species.

The minor characters of *Pentacrinus decorus, i.e.*, those which are of least importance for systematic purposes, present a very remarkable amount of variation. The number of internodal joints may vary almost as much as in *Pentacrinus asterius*, some of the individuals having the internodes as short as those of *Pentacrinus blakei* (seven joints), while in others they may consist of sixteen joints as in *Pentacrinus asterius*; and this character sometimes runs through the whole stem, so that at first sight two individuals will look as if they belonged to entirely distinct species, especially if the development of the basals and arm-divisions be also different in the two cases.

The internodal joints are generally quite smooth externally; but they occasionally bear groups of interradial tubercles at more or less regular intervals, and these tubercles sometimes appear on the nodal joints, thus increasing the prominence of their angles between the cirrus-sockets (Pl. XXXV. fig. 1; Pl. XXXVI. figs. 1, 2). Two individuals are remarkable for the absence of some of the cirri on the stem. Thus in a specimen represented in Pl. XXXVI. fig. 1, one of the cirri is missing at the fourth node, no socket having been developed at all; while in another shown in Pl. XXXVII. fig. 2, there are no cirrus-sockets along one face of the stem to as far down as the twelfth node; and at the eleventh node another socket is absent, so that there are only three cirri at this node, the empty faces of the stem intervening between the cirrus-bearing ones exactly as they do in those nodal joints of *Pentacrinus alternicirrus* which bear three cirri (Pl. XXV.; Pl. XXVI. figs. 13, 14; Pl. XXVII. fig. 2).

The stem of *Pentacrinus decorus*, though more slender than that of *Pentacrinus asterius*, seems like it to grow to a considerable length (compare Pls. XI. and XXXIV.). The longest which I have seen, consisting of fifty internodes, measures 80 cm. Sir Wyville Thomson mentioned one which was about two feet in length;[1] and this seems to have been the original of a drawing which was made for him by Mr. Wild. He spoke of the final joint, which is the epizygal at about the forty-second node, as being worn and rounded; and having subsequently found several other examples in the same condition, he expressed his belief that disengagement at a syzygy is habitual. This is doubtless often the case as in *Pentacrinus wyville-thomsoni* and other species (*ante*, pp. 18–20), though I have not myself met with any specimens in this condition. Moreover, it appears certain that this species may be sometimes permanently fixed. Captain Cole's observation that they may be attached to telegraph cables by the basal extremity of the stem spreading slightly has been noticed already; and the individual mentioned above as having a stem 80 cm. long (which is now in the British Museum) was found by him attached in a slightly different way. The stem is detached from its basal portion at the

[1] Sea Lilies, *The Intellectual Observer*, August 1864, p. 7.

syzygy below the fiftieth node; but it lies along the cable by the next eleven internodes, and is more or less attached to it by means of the cirri.

The variation in the development of the basals in *Pentacrinus decorus* is most extraordinary, and shows what little reliance is to be placed on the characters of this part of the calyx for systematic purposes. In young specimens they are generally quite small and inconspicuous, appearing only as little triangular knobs or rhomboidal pieces which are sometimes just in contact by their lateral angles (Pl. XXXV. fig. 1). But they do not stand out at all from the general plane of the calyx, and simply appear as continuations of the interradial ridges of the top of the stem upon which they rest. In older and even in adult individuals they may retain this condition (Pl. XXXIV. figs. 1, 8; Pl. XXXVI. fig. 3); while in others which are still premature they are a little more prominent (Pl. XXXV. fig. 2); and when a large series of specimens is examined all stages are traceable between this condition and that of the individuals represented in Pl. XXXVI. fig. 1, and Pl. XXXVII. figs. 1, 2. These have large rhomboidal basals, meeting one another laterally in the re-entering angles of the calyx, and standing out as prominent knobs which sometimes extend beyond the interradial ridges of the stem.[1] A somewhat similar though less extensive variation in the development of the basals occurs in the fossil *Antedon scrobiculata* from the Brown Jura.

The ray-divisions of *Pentacrinus decorus* are exceedingly variable. I have met with one case in which the number of three radials, so constant throughout the majority of the Neocrinoids, is considerably exceeded. The radial axillary is primitively the seventh joint above the basal ring, *i.e.*, it is itself a syzygial joint and there are five below it, including the primary or first radials. The second and third of these five joints are united by bifascial articulation, just like the ordinary second radials and axillaries of this species; and in this respect therefore this aberrant form differs from the type represented by *Metacrinus*, in which the second and third joints of the ray are always united by syzygy, whether the axillary be the fifth or eighth in the series of primitive radials (Pl. XXXIX. fig. 1; Pl. XLVI.).

One young specimen of *Pentacrinus decorus* which was brought by Sir Rawson Rawson from Barbados has only ten arms, as is the case in *Pentacrinus naresianus*; while in another dredged by the "Blake" there are only eleven, one of the primary arms dividing on the fifth joint (Pl. XXXV. fig. 1). A third individual (Pl. XXXV. fig. 2) has two arms on each of four rays; but on the fifth ray one of the primary arms divides and one of the secondary arms so formed divides again, so that there are twelve in all. Other examples again may have distichal series developed with considerable regularity all round the calyx, and occasionally also one or more palmar series as well (Pl. XXXVI.; Pl. XXXVII. fig. 2). But the total number of arms rarely exceeds twenty-five in all;

[1] In the specimen represented in Pl. XXXVI. some of the first radials are considerably distorted, apparently as the result of injury and subsequent regeneration.

though Sir Wyville Thomson described a specimen with thirty arms.[1] The irregularity in the number of joints between successive axillaries is very striking, especially as compared with the very constant character of the ray-divisions in the Comatulæ. Taking for example the genus *Actinometra*, we find in *Pentacrinus decorus* the following series of distichals and palmars which are specially characteristic of different groups of the species of that genus.

A.	Ten arms only; the first two brachials united bifascially, and the third brachial a syzygy as in *Pentacrinus naresianus*,	Group of *Actinometra meridionalis*.
B.	Two distichals united by a syzygy,	„ *Actinometra jukesi*.
C.	Two distichals, the axillary not a syzygy,	„ *Actinometra pulchella*.
D.	Three distichals, the axillary a syzygy,	„ *Actinometra parvicirra*.
E.	Two palmars united by a syzygy,	„ *Actinometra typica*.
F.	Two palmars, the axillary not a syzygy,	„ *Actinometra stelligera*.
G.	Two palmars, the axillary a syzygy,	„ *Actinometra multiradiata*.
H.	Three palmars, the axillary a syzygy,	„ *Actinometra bennetti*.

In addition to these, *Pentacrinus decorus* may show numerous combinations of distichal and palmar series such as are characteristic of other groups of Comatulæ, and also certain conditions such as two distichals with the axillary a syzygy, which I have not as yet met with in any *Comatula* at all. These facts well illustrate what has been said above (*ante*, p. 55) respecting the difference between the arms of Pentacrinidæ and Comatulæ.

The rays of *Pentacrinus decorus* and their subdivisions are sometimes in pretty close contact, though rarely flattened laterally; while in other cases they are more or less separated by perisome (Pls. XXXV.–XXXVII.). This perisome is sometimes nearly bare and sometimes plated pretty continuously; and a similar variation is apparent on the upper surface of the disk. This is sometimes covered tolerably closely by rather large plates (Pl. XXXIV. fig. 2); but the plating is not quite so continuous as in *Pentacrinus wyville-thomsoni* and *Pentacrinus alternicirrus* (Pl. XVII. fig. 6; Pl. XXVI. figs. 1, 2). On the other hand, the gaps between the plates, though sometimes comparatively large, are not so extensive as in *Pentacrinus müller*i (Pl. XVII. fig. 10). The plates sometimes bear small blunt spinelets which are possibly tactile in function, as they contain branches from the antiambulacral nerves which extend upwards on to the disk from the envelope of the chambered organ in the calyx (Pl. LIX. figs. 2–4, *ad*). The plates bordering the ambulacra of the disk are narrow and spine-like, often forming a kind of palisade, which is more distinct than in any other type of the Pentacrinidæ (Pl. XXXIV. fig. 2). They become somewhat irregular on the arm-bases (Pl. XXXIII. fig. 6); but further out (Pl. XXXIII. fig. 4) they begin to show signs of a more or less perfect differentiation into the side and covering plates of the pinnule-ambulacra (Pl. XXXVII. figs. 23, 24).

[1] Sea Lilies, *The Intellectual Observer*, August 1864, p. 7.

9. *Pentacrinus mollis*, n. sp. (Pl. XXXIII. figs. 7–10).

Dimensions.

Greatest height of specimen (fig. 9),	10·00 mm.
Least height (fig. 10),	8·00 „
Diameter of calyx across the first radials,	6·50 „
Diameter of disk,	4·75 „

This is a very singular type, and it is with much hesitation that I have referred it to *Pentacrinus;* for it differs considerably from this genus in the relative proportions of the lower parts of the calyx, and its stem is entirely unknown. But on the other hand it presents no character which seems to me of sufficient importance to justify a generic separation.

Its most obvious peculiarity is expressed in the specific name which I have applied to it. The cup, radials, and lower arm-joints, which alone remain, are not formed of the usual hard limestone found in most other Echinoderms. But, externally at any rate, they are of a somewhat leathery texture, and yield readily to pressure, though there appears to be a rather harder core within; while some of the joints show traces of the usual calcareous skeleton, and the disk is extensively plated (Pl. XXXIII. fig. 7).

Nothing remains of the stem except three or four thin stellate joints immediately beneath the calyx. The rays of the star are bent upwards considerably, and enclose in a sort of cup the lower portion of the basal plates with which they correspond in position (Pl. XXXIII. figs. 8–10). There are no traces of broken ligament-fibres on the under face of the lowest remaining stem-joint, and this would seem therefore to have been the upper joint of a syzygial pair with its cirri as yet undeveloped.

The basals which form an entirely closed ring are unusually high for a *Pentacrinus*, but also of considerable width, so as to support the expanding calyx above them. Their outline, so far as it can be seen, is irregularly quadrate, the two lateral edges approaching one another somewhat rapidly until they disappear beneath the upturned stem-joints; while the upper edges meet at a very open angle. The basi-radial suture therefore has five well marked depressions in which the radials rest, and five intervening elevations which mark the middle lines of the basals. The radials are short and widely pentagonal, sloping upwards and outwards at a considerable angle. They have a somewhat strongly marked median ridge which starts from near the basi-radial suture, but disappears before reaching their distal edge, as is well shown in fig. 8; and the distal edge itself is more or less everted, while the dorsal ligament uniting the first and second radials is somewhat prominent. The remaining radials and the lower arm-joints are only properly visible in the anterior and left antero-lateral rays as shown in Pl. XXXIII. fig. 9; for the joints of the other three rays are so shrivelled and contorted as to make their recognition a matter of considerable difficulty. Their general aspect is somewhat diagrammatically represented in Pl. XXXIII. fig. 10.

The second and third radials appear to be united by syzygy. The former are slightly trapezoidal in shape, meeting one another more or less extensively by their lower angles and then diverging. The axillaries are pentagonal, and scarcely wider than the second radials, so that a considerable gap is left between the rays. This, however, is much wider on the front of the calyx than elsewhere, as will be evident from a comparison of figs. 9 and 10 on Pl. XXXIII. It is closed higher up by the approximation of the first brachials of adjacent rays. Where they are properly visible they appear to have the usual somewhat wedge-shaped form; and the next joint was perhaps an axillary. But the condition of the specimen renders the determination of the real nature of the lower arm-joints entirely uncertain. From the mode of division of the ambulacra of the disk, however, it would appear that there were twenty arms (Pl. XXXIII. fig. 7).

The colour is dirty brown with occasional patches of white, indicating the presence of calcareous tissue.

Locality.—Station 235, June 4, 1875; lat. 34° 7′ N., long. 138° 0′ E.; 565 fathoms; green mud; bottom temperature, 38°·1 F. One mutilated specimen.

Three much mutilated individuals of *Eudiocrinus japonicus* were obtained at the same Station; but they exhibit no trace of the extraordinary deficiency of limestone in the skeleton which distinguishes *Pentacrinus mollis*. The height of the basals and the peculiar way in which they are received into a sort of cup formed by the uppermost stem-joints distinguish this type very markedly from all the other Pentacrinidæ. For the stem-joints of this family usually decrease rapidly in size towards the top of the stem, the upper ones being concealed within the concavity formed by the lower faces of the basals, as is well shown in Pl. XXXIII. fig. 5. But it is of course possible that this may also be the case even in the doubtful *Pentacrinus mollis*, though on a smaller scale.

Genus *Metacrinus*, n. gen.

Characters of the Genus.

The petaloid sectors of the faces of the stem-joints are bordered by a few large ridges, of which the smaller proximal ones meet those of adjacent sectors in the interpetaloid spaces, while the larger distal ridges reach the outer edge of the joint. The internodes of six to thirteen joints. Nodals fully occupied by the cirrus-sockets which reach their upper edge; supra-nodals incised to receive the bases of the upturned cirri. These are long, consisting of forty or fifty uniform joints, and vary but little in appearance. The lower cirri often smaller than those about the twelfth node.

Basals large, rhomboidal, or hexagonal, and in close contact. Their lower angles are generally distinctly produced downwards. Four to six radials, the second a syzygy and bearing a pinnule, as do the remaining ones till just before the palmar axillary. The

fourth radial is sometimes a syzygy. The rays generally divide four and sometimes five times; and their subdivisions are equal in value or nearly so. The first joint after each axillary bears a pinnule, and the third is usually a syzygy.

The terminal parts of the arms have a large number of undeveloped pinnules. Those on the lowest parts of the rays have large, thick joints, the basal ones cuboidal and the rest oblong. Those borne by the radials and lower distichals receive their ambulacra direct from the peristome, or from the primary ambulacra of the disk.

Remarks.—The name *Metacrinus* for this very well characterised genus originated with Sir Wyville Thomson; but he drew up no diagnosis of it. Indeed it was only by finding the name in his handwriting upon a proof of Pl. XLVII. that I was informed of his recognition of the type as distinct from *Pentacrinus*, under which name it had been mentioned in the Station Book, and in various publications that dealt with the work of the Challenger in the Pacific. I had known of the existence of a second living genus of Pentacrinidæ for some months before the Challenger and "Blake" Crinoids came into my hands. For my friend Mr. Charles Stewart, F.L.S., the present Curator of the Hunterian Museum at the Royal College of Surgeons, had shown me early in 1881 a very fine dry specimen which had been obtained in the neighbourhood of Singapore by one of the ships belonging to the Eastern Telegraph Company. It was accompanied by a stem-fragment of another species which I now know to belong to the same genus. Thanks to his kindness, I have been able to describe them recently,[1] together with yet another species which had been dredged in the Japanese Seas by Dr. Döderlein, the Conservator of the Natural History Museum at Strassburg, who courteously placed it in my hands for this purpose. Eleven species were dredged by the Challenger, and there is another which I have not examined personally. It was dredged by the famous "Vega" in Yeddo Bay, during her stay in Japan in October 1879; but no description of it has yet been published. It is at present in the hands of Prof. S. Lovén of Stockholm; and with his characteristic kindness he not only sent me some fragments of the stem, but also allowed Mr. Percy Sladen, who was examining the Starfish collection in the Stockholm Museum, to draw up a description of it for me. So carefully was this done, that I have been enabled to recognise the affinities of the type, and to assign it a place in the classification of the genus which appears on p. 344.

Both the calyx and the stem of *Metacrinus*, but especially the former, present very striking differences from the corresponding parts in *Pentacrinus*. In the latter genus it is quite the exception for the number of radials to exceed three, which is so constant in *Apiocrinus*, *Millericrinus*, *Encrinus*, and *Comatula*; and even when there are more, none of them bear any pinnules. Thus there is no pinnule on the third joint of the abnormal ray of *Pentacrinus mülleri* represented on Pl. XV. fig. 2, in which the axillary is the fourth joint above the basals; nor on any of the five joints below the radial axillary

[1] On Three New Species of Metacrinus, *Trans. Linn. Soc. Lond.* (Zool.), ser. 2, vol. ii. pp. 435–447, pls. l.–lii.

(itself a syzygy) in a singular specimen of *Pentacrinus decorus*, which was dredged by the "Blake" (*ante*, p. 336).

In *Metacrinus*, however, the number of primitive radials is typically either five or eight. In both cases the second and third of these eventually become united by syzygy, and the latter, which corresponds exactly to the third radial in the abnormal *Pentacrinus müllerí* already mentioned (Pl. XV. fig. 2), bears a pinnule, as does also the next joint, which is sometimes followed by the axillary (Pl. XXXIX. fig. 1; Pl. XLIII. fig. 2). When there are eight primitive radials the original fifth and sixth joints become united by syzygy in the same way; so that the ray is described as consisting of six joints, of which the second and fourth are syzygial, both of these as well as the third and fifth bearing pinnules (Pl. XLVI.; Pl. L. fig. 1).

These pinnules also afford a very good distinguishing character of *Metacrinus*. Their lower and middle joints are very large and massive, having a considerable vertical height in addition to their thickness from side to side; while one or two of the basal joints are nearly cubical in appearance (Pl. XXXIX. fig. 1; Pl. XLIII. figs. 2, 4; Pl. XLVI.; Pl. XLVIII. fig. 1; Pl. L. fig. 1). The later joints, while remaining long and high, gradually diminish in breadth so that they come to be prismatic, with a sharp dorsal edge. The distichal and palmar pinnules have the same characters as those on the radials, though in a less prominent degree.

The shape and large size of their joints are well shown in Pl. XXXIX. fig. 2, and in Pl. XLIII. fig. 2. There is no regularity as to the side of the ray on which the first pinnule occurs; so that the same interradial space may be occupied by the first pinnules of two rays as is shown on the right of Pl. XXXIX. fig 1; while on the left of the same figure the second pinnules of two rays also occur in the same interradius. This not unfrequently causes a certain amount of crowding; and it is not uncommon for one of the later radial or lower distichal pinnules to be very much flattened laterally and almost knife-like in appearance, while the corresponding pinnules on the other rays of the same individual are large and massive.

About the level of the distichal axillary, or rather farther out if the number of arms be large, the stout lower pinnules begin to lose their distinguishing characters and to pass gradually into the ordinary pinnules of the free arms. The transition is very difficult to explain without a long series of figures illustrating its successive stages, and it varies a good deal in different types; but it may be generally described as a flattening of the pinnule-joints (as it were) against the arm and against the succeeding pinnules. They thus retain a considerable height in a vertical (dorsoventral) direction and have a sharp dorsal edge, with the exception of the lowest joints which are set in a different plane from their successors and are often of a much greater width. This is the case, for example, in the palmar and lower brachial pinnules of *Metacrinus moseleyi* as seen on the left hand ray of the specimen represented in Pl. XLVI.; while in *Metacrinus*

murrayi, *Metacrinus costatus*, *Metacrinus nodosus*, and *Metacrinus wyvillii* the distichal pinnules are flattened as well as their successors, and all have wide basal joints, as shown in Pl. XLVIII.

The lower pinnules of *Pentacrinus* do not present anything like the characters of those of *Metacrinus*, the only approach to this type being the relatively large size of their lower joints in *Pentacrinus asterius* (Pl. XIII. fig. 1) and in some forms of *Pentacrinus mülleri* (Pl. XV. fig. 3); while the distichal pinnules never receive their ambulacra direct from the peristome or from one of the five primary ambulacra of the disk, as do the radial and lower distichal pinnules of *Metacrinus* (Pl. XXXIX. fig. 2; Pl. XLIII. fig. 3; Pl. L. fig. 3). This character is at once sufficient to separate the disks of the two genera; but it does not produce any important effect upon their external appearance in the same way as do the large number of radials and the great size of the pinnules borne by them. There are other very striking features, however, which considerably affect the general facies of the species of *Metacrinus*. There is always a much greater length of the terminal portions of the arms which have undeveloped pinnules than in any species of *Pentacrinus;* and this gives a curious rat-tailed appearance to the general plume of arms. Compare *Pentacrinus* (Pls. XI., XV., XVIII., XIX., XXV., XXVIII., XXXI., XXXIV.), *Metacrinus* (Pls. XXXVIII., XL., XLII.–XLIV., XLVIII., XLIX., LI., LII.).

An examination of these Plates will also bring out the more striking differences in the characters of the stems of the two types. The cirri of *Pentacrinus* vary considerably in length and in appearance, being long and stout in *Pentacrinus asterius* and *Pentacrinus mülleri* (Pls. XI., XIV.); shorter in *Pentacrinus wyville-thomsoni*, though still stout (Pl. XIX.); and slender in *Pentacrinus naresianus*, *Pentacrinus decorus*, and *Pentacrinus blakei* (Pls. XXVIII., XXXI., and XXXIV.), the number of joints varying from twenty to fifty. In *Metacrinus*, however, the mature cirri nearly always have over forty joints, which are generally moderately stout; though of course they are not absolutely so large in the less robust types like *Metacrinus costatus* (Pl. XLIX.) and *Metacrinus nodosus* (Pl. L.), as in *Metacrinus angulatus* (Pl. XXXVIII.), *Metacrinus cingulatus* (Pl. XL.), and *Metacrinus murrayi* (Pl. XLII.). In the three types last mentioned, and also in *Metacrinus interruptus* (Pl. LII.), the cirri about the tenth or twelfth node are larger than those below them; but in other species this difference is not so manifest. All the species of the genus, however, have the older cirri more or less directed upwards, as is especially well shown in *Metacrinus angulatus* (Pl. XXXVIII.), *Metacrinus wyvillii* (Pl. XLVIII.), *Metacrinus interruptus* (Pl. LII.), and *Metacrinus tuberosus* (Pl. LIII.); though it is less marked in *Metacrinus varians* (Pl. XLIV.). This character occurs in no *Pentacrinus* excepting *Pentacrinus wyville-thomsoni* (Pl. XIX. fig. 1), and is by no means constant in that type. But the result of it is that the supra-nodal joint takes a considerable share in the formation of the cirrus-socket, being more or less deeply incised

to receive the wide basal joints of the cirri; so that its re-entering angles are deeper than those of an ordinary internodal joint (compare Pl. XXXIX. figs. 8, 9; and Pl. LIII. figs. 2, 4). The infra-nodal joints, however, are less deeply incised than those of *Pentacrinus*, and are sometimes not modified at all, as in *Metacrinus interruptus* and *Metacrinus rotundus*. This is the case in *Pentacrinus wyville-thomsoni* (Pl. XIX. figs. 3, 4), in which the lower edge of the cirrus-socket of the nodal joint projects outwards beyond the level of the infra-nodal joint below it, while the supra-nodal is only slightly modified to receive the bases of the upward projecting cirri. Traces of a similar rim at the lower edge of the cirrus-socket are to be seen in *Metacrinus interruptus* (Pl. LII. fig. 2).

I know of no characters by which isolated internodal joints of *Metacrinus* can be distinguished from those of *Pentacrinus*, the relations of the teeth to the petaloid sectors being the same in both types. But the number of internodals is much more constant in *Metacrinus* than in *Pentacrinus*. In the latter genus there may be only one or two, as in *Pentacrinus maclearanus* (Pl. XVI. fig. 1); or about sixteen in *Pentacrinus asterius* (Pl. XI.), and about forty in *Pentacrinus wyville-thomsoni*; whereas in *Metacrinus* the limits of variation are from six or seven in *Metacrinus wyvillii* (Pl. XLVIII.) to thirteen in *Metacrinus murrayi* (Pl. XLII.); so that this character is of less value in the classification of the species than it is in *Pentacrinus*.

The geographical range of *Metacrinus* is much more limited than that of *Pentacrinus*. Neither genus has been found in the Pacific east of long. 170° W.; but there are no Atlantic species of *Metacrinus*. *Pentacrinus* was obtained without *Metacrinus* at Stations 171 and 175 in the South Pacific; while *Metacrinus* occurred alone at Station 209 (among the Philippines), and also in considerable abundance and variety at Station 192, in the Arafura Sea. It extends as far west as Singapore, and is represented by two species in Japanese waters, where no *Pentacrinus* is known, excepting the doubtful *Pentacrinus mollis* (Pl. XXXIII. figs. 7–10). On the other hand, *Metacrinus* has not been met with below 630 fathoms, while *Pentacrinus* has been dredged at 1095 fathoms in the Atlantic, and 1375 fathoms in the Pacific Oceans.

The mutual relations of the thirteen species of *Metacrinus* in which the calyx is known, are shown in the following Table. The Challenger species are numbered 1 to 11, and the letters P. H. C. are appended to those which I have recently described in the Transactions of the Linnean Society. The "Vega" specimen, which concludes the list, has not yet been described. There are two other species of the genus (one obtained by the Challenger) which are known as yet only by the characters of their stems; and I have therefore been obliged to place them in a separate list, as the number of radials in the cup is still an unknown quantity.

Genus *Metacrinus* (Wyville Thomson, MS.), P. H. Carpenter, 1884.

Four radials; the second a syzygy.

- Eight to twelve internodal joints with horizontal ridges.
  - Ridges incomplete, . . . — 1. *angulatus*, n. sp.
  - Ridges continuous, ... — 2. *cingulatus*, n. sp.
- Ten to thirteen internodal joints.
  - Lower parts of rays smooth. Forty-five cirrus joints.
    - Thirteen internodal joints with incurved sides. Interarticular pores to thirteenth node. — 3. *murrayi*, n. sp.
    - Ten or twelve internodal joints with flat sides. Interarticular pores to tenth node. — 4. *nobilis*, n. sp.
  - Lower parts of rays have raised distal edges. Sixty-five cirrus-joints. Interarticular pores to eighteenth node. — *superbus*, P. H. C.
- Six to ten internodal joints with nearly flat sides. Interarticular pores to about the sixth node. — 5. *varians*, n. sp.

Radials irregular; usually five or six; the second and also the fourth often a syzygy.

- Seven to nine internodal joints; the larger ones with a strong median girdle. — 6. *moseleyi*, n. sp.
- Eleven or twelve smooth internodal joints, . . . — *rotundus*, P. H. C.

Six radials; the second and fourth syzygies.

- Six to nine internodal joints.
  - Three ray-divisions. Cirrus-facets as high as the nodal joints. Five to eight internodals with horizontal ridges. — 7. *wyvillii*, n. sp.
  - Four ray-divisions. Nodal joints higher than cirrus-facets.
    - Stem with strong interradial ridges and nearly smooth, slightly hollowed sides. Seven or eight internodals. — 8. *costatus*, n. sp.
    - Eight or nine internodals, with flat tubercular sides. Angles of nodals enlarged. — 9. *nodosus*, n. sp.
- Ten or eleven internodal joints.
  - Stem pentagonal, with a tubercle at each angle and ridges on the sides, but not forming a complete girdle. Usually eight distichals. — 10. *interruptus*, n. sp.
  - Rounded stem without ridges. Usually ten distichals. — The "Vega" specimen.

Angles of stem sharp and produced outwards.

- Seven internodals with median tubercles. Infra-nodals not incised. — 11. *tuberosus*, n. sp.
- Eleven internodals with slight horizontal ridges. Infra-nodals not incised. — *stewarti*, P. H. C.

1. *Metacrinus angulatus*, n. sp. (Pls. XXXVIII., XXXIX.).

Dimensions.

Greatest length of stem, terminating at the thirty-fifth node,	38·50 cm.
Diameter of stem,	5·75 mm.
Longest cirrus (fifty-seven joints),	53·00 „
Diameter of calyx,	8·25 „
Diameter of disk,	20·00 „
Length of arm (one hundred and ten joints),	90·00 „
Length of large distichal pinnule (twenty joints),	25·00 „
Length of first pinnule after tertiary axillary (twelve joints),	10·00 „

Stem robust, with a sharply pentagonal outline. Eight to twelve internodal joints with but slightly crenulated edges. Their faces are distinctly stellate, while the angles are sharpened and slightly produced outwards; and their sides bear strong horizontal ridges, the edges of which are coarsely denticulate. Nodal joints more distinctly stellate in outline and without horizontal ridges. The cirrus-facets reach closer to their upper than to their lower edges, while the supra-nodal joints are slightly incised to receive the bases of the large cirri, which are mostly directed upwards, and are longest at the twelfth node. They usually consist of forty-five to fifty-five stout joints, which are very uniform in appearance except at the two ends. The lower joints are quite short, and the distal edges are longer than the proximal ones, so that the joints seem to have slight dorsal projections at their distal ends. The interarticular pores terminate between the tenth and twelfth nodes.

Basals widely hexagonal, united into a complete ring, and rather prominent on the exterior of the calyx. They are much higher in the middle line than at the lateral edges, and the lower angle is often produced considerably downwards over the upper stem-joints. Four radials, the first comparatively short and the second a syzygy with a pinnule on the epizygal, the third also bearing a pinnule and the last axillary. Rarely more than three divisions of the rays, which are in close apposition, being only separated by the bases of the large lower pinnules. Forty to fifty arms, generally consisting of about one hundred slightly overlapping joints beyond the last axillary. Primary arms of six to ten distichals (usually eight or nine), of which the second or third is a syzygy. Secondary arms of ten to fourteen palmars, sometimes as many as twenty, the third of which is usually a syzygy. Tertiary arms rare; consisting when present of fourteen to thirty joints, the third of which is a syzygy. There is generally a syzygy in the third brachial of the free arm. Another somewhere between the tenth and thirtieth brachials, and others at intervals of six to twelve joints.

A pinnule on the epizygal of the second radial, and on the first joint after each axillary. The first pinnules, as far as the beginning of the secondary arms, are much larger than their successors, consisting of about twenty joints, the lowest of which are

very massive, and generally somewhat cuboidal; while the next few are narrower with flattened sides, but still of great thickness in a dorsoventral direction. The thickness gradually diminishes, and the outer part of the pinnule consists of moderately long, somewhat flattened joints, with the dorsal edges sharpened and projecting slightly forward over the bases of their successors. The distichal pinnules on the outer sides of the ray are longer and have somewhat larger joints than those borne by the radials. Beyond the distichal axillary, the size of the pinnules gradually decreases, the lower joints becoming at first prismatic and then flattened, but remaining distinctly larger than their successors for some little distance beyond the palmar axillaries. The later pinnules are short and styliform.

The disk bears numerous small scaly plates, which are more thickly grouped on the anal tube than elsewhere. Disk-ambulacra strongly but irregularly plated; those of the arms distinctly above the arm-groove, and supported by regular bifid plates which become differentiated on the pinnules into covering plates and ill defined side plates.

Colour when fresh—the stems almost white, and the crowns light yellow or light reddish-orange (Moseley); in spirit, white or whitish-brown.

Locality.—Station 192, September 26, 1874; in the Arafura Sea, off the Ki Islands; lat. 5° 49′ S., long. 132° 14′ E.; 140 fathoms; blue mud. Seven specimens, and possibly more.

Remarks.—This species is readily distinguished from its nearest ally (*Metacrinus cingulatus*) by the characters of its stem-joints (Pl. XXXIX. figs. 3–11). They are much more sharply stellate than in that type (Pl. XLI. figs. 1–3), having deeper re-entering angles; while the horizontal ridges on the sides of the internodal joints are generally not continuous, but interrupted at the angles, which are somewhat produced outwards (Pl. XXXIX. fig. 3). One specimen presents a curious variation in this respect. The horizontal ridges on the thicker joints are enlarged so as to have a somewhat diamond shaped aspect, with more or less produced lateral angles (Pl. XXXIX. fig. 11); and when this ridge is large it shows itself very plainly in a terminal view of the joint-face, outside the line of teeth (compare Pl. XXXIX. figs. 8 and 11). In this specimen too the downward extension of the basals over the upper stem-joints is especially well marked, and the supra-nodal joint is rather more hollowed to receive the cirrus-bases than it is in the type. The stems of five specimens all terminate below in a nodal joint. In two cases there appears to have been an attached portion of stem beneath; for the surface of this lowest nodal joint is comparatively fresh and its central canal visible; but in the other three stems this surface is somewhat worn, and I cannot make out the opening of the central canal, which appears to have been closed up, the animal living in a semi-free condition like *Pentacrinus wyville-thomsoni*, *Pentacrinus maclearanus*, or *Pentacrinus alternicirrus*. The respective lengths of these stems are as follows:—(1) 38·5 cm. long, closed at the thirty-fifth node; (2) 23·5 cm. long, closed

at the twenty-fourth node; (3) 22·5 cm. long, closed at the twenty-fifth node. The individuals of this species present various forms of monstrosity, some of which have already been mentioned:—(1) The presence of six joints in one ray, of which the second and the axillary are syzygies, thus approaching the other group of *Metacrinus* species. (2) The presence of eleven radials on one ray, which recalls the irregularities of the Palæocrinoids. (3) The eighth joint of one of the primary arms is not a distichal axillary as usual, but it is swollen and bears a slightly larger pinnule than the preceding joint, so that it resembles an axillary with unequal faces. Fourteen joints further on there is an axillary which corresponds to that on the secondary arms of other rays. (4) The presence of a second smaller anal tube at the side of the ordinary one (Pl. XXXIX. fig. 2), an individual of *Myzostoma wyville-thomsoni*, von Graff, having attached itself between the two. (5) The two arm-trunks borne by one of the palmar axillaries each have a syzygy in the third brachial, and then unite again into a single trunk. The fourth joint of the right-hand arm has the shape of an axillary reversed, *i.e.*, it has two proximal faces, one of which meets the epizygal of the third brachial, and the other the fourth brachial of the left-hand arm. It bears a pinnule on its left side, and as it is the fourth joint of one arm-trunk, and the fifth of the other, the ordinary sequence of the pinnules is uninterrupted, and continues normal throughout the rest of the arm which is borne by this reversed axillary.

2. *Metacrinus cingulatus*, n. sp. (Pl. XL., Pl. XLI. figs. 1–4).

Dimensions.

Length of stem to thirty-third node,	35·00 cm.
Diameter of stem,	5·50 mm.
Longest cirrus (fifty joints),	51·00 „
Diameter of calyx,	8·00 „
Diameter of disk,	18·00 „
Length of arm (one hundred joints),	135·00 „
Length of large distichal pinnule (twenty-five joints),	28·00 „
Length of first pinnule after tertiary axillary (fifteen joints),	10·00 „

Stem robust, with a sharply pentagonal outline. Six to fifteen (usually eight to twelve) internodal joints, with moderately crenulated edges. Their faces are bluntly stellate, with shallow re-entering angles; while their sides bear strong horizontal ridges which are slightly more prominent at the angles of the stem, and are often marked by irregular indentations. The nodal joints are more distinctly stellate, and have no ridges except at the angles and where the cirrus-facets are absent. These reach closer to the lower than to the upper edges of the nodal joints, but the incision of the supra-nodals is fairly distinct. The cirri have about forty to fifty tolerably uniform joints, and are

longest between the eleventh and twelfth nodes. The interarticular pores end between the eighth and tenth nodes.

Basals prominent, more or less extended downwards. Radials four, the second a syzygy. Rarely more than four divisions of the rays, giving forty or fifty arms, which consist of about one hundred joints beyond the last axillary, the basal ones slightly overlapping. Primary arms of six to eight, or sometimes ten distichals, of which the second or third is a syzygy. Secondaries of ten to fifteen (usually twelve to fourteen) palmars, the third generally a syzygy. Tertiary arms rare, consisting of fourteen to twenty-six (usually eighteen to twenty) joints, the third of which is a syzygy. In rare cases there is another axillary after twenty joints more. There is generally a syzygy in the third brachial of the free arm, another between the seventh and twenty-sixth, and others at intervals of six to eighteen joints. The distichal pinnules have large outer joints, and are therefore larger on the whole than those on the radials, though the basal joints are generally less massive than in the radial pinnules. All the pinnules, and especially the lower ones, have a serrate dorsal edge. The disk bears numerous small plates, which are not very closely set, except in the anal interradius. The ambulacra of the disk and arm-bases are supported by irregular elongated plates, the latter being distinctly above the arm-groove, with a few ambulacral plates at their sides. The brachial ambulacra protected by smaller bifid plates, which become differentiated on the pinnules into covering and side plates.

Colour when fresh—the stems almost white, and the crowns light yellow or light reddish-orange (Moseley); in spirit, white.

Locality.—Station 192, September 26, 1874; in the Arafura Sea, off the Ki Islands; lat. 5° 49′ S., long. 132° 14′ E.; 140 fathoms; blue mud. Two specimens.

Remarks.—This species is at first sight not unlike *Metacrinus angulatus* (Pl. XXXVIII.), having about the same number of internodal joints in the stem, and a nearly identical arrangement of the arm-divisions. The stem-joints, however, are very different in the two types. The horizontal ridges, which are interrupted at the angles of the stem in *Metacrinus angulatus* (Pl. XXXIX. figs. 3, 11), are usually continued right round the joints in *Metacrinus cingulatus* (Pl. XLI. figs. 1, 3); and they appear also as enlargements of the angles of the nodal joints (Pl. XLI. fig. 2), which are much less sharp than in *Metacrinus angulatus* (Pl. XXXIX. fig. 4). As a rule too there are generally slightly fewer joints between the successive axillaries of the dividing rays than in the latter species, but the character of the arms and of the pinnules which they bear is very much the same in both.

The two specimens of *Metacrinus cingulatus* which were obtained by the Challenger differ somewhat in their characters, and each exhibits a certain amount of variation. In the smaller individual there is an irregularity in one of the rays. The fourth or axillary radial is not articulated to the preceding joint, as is usually the case, but the two

are united by syzygy. The third radial therefore, being a hypozygal, bears no pinnule. But the normal number of pinnules, one on each side of the ray, is still maintained; for the second radial, itself a syzygial joint, bears a pinnule on each side.

The stem of this specimen, which is broken at the bottom, tapers slightly downwards, and has tolerably regular internodes, with five cirri at each node in the usual way. The stem of the other individual, however, does not decrease in size at its lower end, which terminates in a nodal joint with a freshly exposed under surface. The internodes of this stem are very irregular in length, and generally consist of one or two joints more than in the smaller specimen, while the development of cirri at the nodes is extremely irregular. No less than ten of the thirty-three remaining nodes have one or more cirri deficient, as shown in the following Table :—

Node.	Missing Cirri.	Node.	Missing Cirri.
5th	2	20th	2
8th	1	24th	2
9th	3	27th	4
10th	1	30th	4
13th	1	33rd	2

In the lower part of the stem there is no trace of the absent sockets, which are replaced by ridges like those on the internodal joints; but in the middle and upper parts the socket is present, though imperfectly developed, especially at the fifth node. At the thirteenth, the place of the socket is entirely taken up by a group of sessile Cirripedes (*Verruca*).

3. *Metacrinus murrayi*, n. sp. (Pl. XLI. figs. 12–17; Pl. XLII.).

Dimensions.

Length of stem to eighteenth node,	184·00 mm.
Diameter of stem,	6·75 „
Longest cirrus (forty-eight joints),	43·00 „
Diameter of calyx,	41·00 „
Diameter of disk,	21·00 „
Length of arm (one hundred and fifteen joints above tertiary axillary),	100·00 „
Length of pinnule on second radial (fifteen joints),	18·00 „
Length of first palmar pinnule (seventeen joints),	23·00 „
Length of first pinnule after tertiary axillary (eighteen joints),	14·00 „

Description of an Individual.—Stem robust and of a rounded pentagonal form, with very shallow re-entering angles. Internodes composed of thirteen joints, with smooth sides and faintly crenulated edges. The supra-nodal joints are slightly incised, but the

articular surfaces of the wide and deep cirrus-sockets are limited to the nodal joints, which are markedly stellate in form, though their angles are not produced outwards. The infra-nodals are also deeply notched by the downward extensions of the cirrus-sockets. Cirri composed of about forty-five joints, almost all of which, and especially the basal ones, are wider than long. Interarticular pores disappear at the thirteenth node.

The basals appear externally as rhomboidal knobs, but they extend laterally to meet their fellows in the re-entering angles of the calyx. Four radials, of which the first is relatively short and wide, and the second a syzygy. The rays divide four, and occasionally five, times, giving about ninety arms. These consist of about one hundred and ten joints above the tertiary axillaries, and, like the rays, are quite smooth at the base, only becoming serrate towards the extremities. Four or rarely six distichals in the primary arms; eight or ten palmars in the secondaries; and the tertiaries of eight to eighteen (usually twelve or fourteen) joints. The next division (when present) occurs after about fourteen or sixteen (ten to twenty-four) joints more. The third joint after each axillary is usually a syzygy. Another between the tenth and thirtieth brachials, and then an interval of five to thirteen joints between successive syzygies.

The two radial pinnules, and also those on the lower distichals, have one or two massive basal joints; but the following joints, though long and moderately thick, are very much flattened laterally, so that the dorsal surface is reduced to a mere edge. The longest pinnules are those immediately above and below the distichal axillary, and are less compressed than their predecessors, so that the joints are more uniform in appearance, though the lower ones are relatively large and cuboidal. The palmar pinnules are all long; but the size begins to diminish beyond the axillaries, rapidly at first, and afterwards somewhat slowly.

The disk is thickly covered with plates which are small and more closely set upon the anal tube than elsewhere. Brachial ambulacra not much above the arm-groove, and supported by bifid plates which are differentiated into side and covering plates about the middle of the pinnules.

Colour in spirit—calyx and arm-bases grey; arms and stem nearly white, but the tips of the arms light brown.

Remarks.—The fine specimen which forms the subject of the above description has unfortunately lost most of its arms in the usual way, viz., by fracture at one or other of the lower syzygies. In the frequency of its ray-divisions, in the constant presence of supra-palmars, and in the diameter of its stem, it ranks among the largest types of recent Pentacrinidæ, and I have much pleasure in associating it with the well known name of Mr. John Murray.

The species which it most nearly resembles is *Metacrinus nobilis*, from Station 192, near the Ki Islands; though the two forms differ considerably in the characters of the

stem, as may be seen by comparing figs. 5–7 and figs. 15–17 on Pl. XLI. The whole stem of *Metacrinus murrayi* is slightly grooved along the interradial lines (fig. 15), so that the pentagonal outline of the internodal joints has shallow re-entering angles (fig. 17), while those of the nodal joints are sharper than in *Metacrinus nobilis* (figs. 6, 16). The modification of the supra-nodals is about the same in both types, but the infra-nodals of *Metacrinus nobilis* are more cut away to receive the cirrus-bases than are those of *Metacrinus murrayi* (Pl. XLI. figs. 5, 15). The internodes of the stem in the latter species are slightly longer, and the interarticular pores reach farther from the cup than in *Metacrinus nobilis*, but there are fewer joints in the primary arms, and the dorsal edges of the pinnules are less serrate (Pl. XLI. figs. 9, 10; Pl. XLII. figs. 2, 3). Of the two remaining species with smooth stems and four radials, *Metacrinus superbus* is readily distinguished from *Metacrinus murrayi* by the great size of the cirri and the roughness of the arm-bases; while the stem of the smaller *Metacrinus varians* has considerably shorter internodes and nearly flat sides.

The habitat of *Metacrinus murrayi* is unfortunately unknown, no record having been kept of the Station at which it was dredged. It may perhaps be one of the two species which are noted in Sir Wyville Thomson's diary as having been obtained at Station 210 (Panglao), no Crinoid having reached me with the label of this Station. On the other hand, it may have been found at Station 192 (Ki Islands) or Station 214 (Meangis Islands). A Cirripede attached to one of the cirri was identified by Dr. Hoek as *Scalpellum balanoides*. This species is abundant at Station 192; and Dr. Hoek had seen individuals from no other locality. Under these circumstances one would almost have been justified in assigning *Metacrinus murrayi* to that Station; but Dr. Hoek has also recognised *Scalpellum balanoides* on a cirrus of *Metacrinus varians* which I sent him from Station 214. Either of these Stations therefore, to say nothing of Station 210, might have been the habitat of *Metacrinus murrayi*.

4. *Metacrinus nobilis*, n. sp. (Pl. XLI. figs. 5–11; Pl. XLIII.).

Dimensions.

Length of stem to twenty-fifth node,	28·00 cm.
Diameter of stem,	7·00 mm.
Longest cirrus (forty-eight joints),	46·00 „
Diameter of calyx,	9·00 „
Diameter of disk,	21·00 „
Length of arm (one hundred and twenty joints above tertiary axillary),	125·00 „
Length of large distichal pinnule (twenty-three joints),	27·00 „
Length of first pinnule after tertiary axillary (thirteen joints),	14·00 „

Stem robust, with a simple pentagonal outline and smooth, flat sides. Usually ten or twelve internodal joints, with slightly crenulated edges. Nodal joints bluntly stellate, with

wide sockets which take up their whole height and encroach considerably both on infra-nodal and on supra-nodal joints. The cirri have about forty-five tolerably uniform joints, and are longest between the twelfth and fourteenth nodes. The interarticular pores end at the tenth node.

Basals prominent, with slight downward extensions. Radials four, rather strongly convex, the second a syzygy. Generally four, and sometimes five divisions of the rays, giving seventy arms or more. These have from one hundred to one hundred and twenty joints beyond the last axillary, and are smooth at the base; but their middle and outer portions are markedly serrate in the medio-dorsal line. Primary arms usually of five distichal joints, one or sometimes two of which are syzygial. Eight or nine palmars in the secondary arms, the second or third of which is a syzygy. Tertiaries of twelve to twenty joints (usually about fifteen), with the third a syzygy. In a few cases there is another division after about twenty joints more. There is generally a syzygy in the third brachial of the free arm; another between the twelfth and thirty-seventh brachials, and others at intervals of four to thirteen joints.

The pinnules on the radials and lower distichals are all very long and much compressed above the enlarged basal joints, while their terminal portions have a serrate dorsal edge. The following pinnules, as far as the tertiary axillaries, have wide and somewhat prismatic basal joints like those lower down on the rays, but with more curved sides, and consisting of more uniform joints, the dorsal edges of which project forwards.

Disk rather closely plated, especially in the anal interradius and along the ambulacra. Brachial ambulacra partially withdrawn into the arm-groove, and supported by irregularly shaped plates. Side plates not differentiated till near the ends of the pinnules.

Colour when fresh—the stems almost white, and the crowns light yellow or light reddish-orange (Moseley); in spirit, white, with traces of light brown.

Locality.—Station 192, September 26, 1874; in the Arafura Sea, off the Ki Islands; lat. 5° 49′ S., long. 132° 14′ E.; 140 fathoms; blue mud. Two large specimens, one of which has lost all its arms, and one smaller varietal form.

Remarks.—This fine species is readily distinguished from *Metacrinus murrayi* by its flat ungrooved stem (Pl. XLI. fig. 5), with shorter internodes and more markedly incised infra-nodal joints (Pl. XLIII. fig. 1). The primary arms are generally longer than in that type, and the extremities of the arms and pinnules more serrate. *Metacrinus varians*, which resembles *Metacrinus nobilis* in having a flat ungrooved stem (Pl. XLVII. figs. 6, 8), is altogether a smaller type with shorter internodes and no axillaries after the palmars, so that the number of arms does not exceed forty; while the large *Metacrinus superbus* has many more cirrus-joints and its arm-bases uneven, owing to the thickness of the proximal and distal edges of the joints.

Together with the two large specimens of *Metacrinus nobilis* which agree very well in their general characters, there was also obtained a fragment of stem which appears to belong to this species. The internodes are much shorter than in the type, and contain a number of thin joints which are evidently newly formed; while there are traces of interarticular pores in its upper portion. As, however, the cirri are all directed downwards it is possible that the individual was in a semi-free condition, with a comparatively short stem like *Pentacrinus maclearanus* (Pl. XVI.) or *Pentacrinus alternicirrus*. At one of the nodes a cirrus-socket is totally undeveloped; and the same appears to be the case at another node farther down the stem, where a large *Verruca* covers the whole of one side of the nodal joint, also extending on to those above and below it.

Besides the two large specimens mentioned above there was also obtained at Station 192 a smaller individual which agrees so closely with the type of this species that I find some difficulty in separating it, although the two forms appear at first sight to be totally different. The stem, which is much more rounded than in the type (Pl. XLI. figs. 7, 8), is barely 5 mm. in diameter; and although the internodal joints are generally smooth, their angles are sometimes slightly produced outwards, while indications of horizontal ridges appear here and there below the twelfth node. The grouping of the arm-divisions is essentially the same as in the larger type, so far as can be made out in the fragmentary condition of the dried specimen; and in default of further information respecting its characters, I do not see how to classify it otherwise than as an immature or smaller variety of *Metacrinus nobilis*.

5. *Metacrinus varians*, n. sp. (Pl. XLIV.; Pl. XLVII. figs. 6–12).

Dimensions.

Length of stem to thirty-second node,	34·00 cm.
Diameter of stem,	5·25 mm.
Longest cirrus (fifty joints),	40·00 „
Diameter of calyx,	8·50 „
Length of arm (ninety joints beyond palmar axillary),	85·00 „
Length of distichal pinnule (eighteen joints),	16·00 „
Length of first pinnule after palmar axillary (nineteen joints),	12·00 „

Stem moderately robust, with a simple pentagonal outline, its sides being nearly flat, and scarcely grooved at all. Six to ten internodal joints (usually eight or nine), with smooth sides and but faintly crenulated edges. Nodal joints bluntly stellate, with moderately wide sockets which take up their whole height, extending well downwards on to the infra-nodals and also upwards on to the supra-nodals. Cirri of forty-five to fifty very uniform joints, the lowest of which are but little wider than their successors; the

lower cirri not specially shorter than the upper. Interarticular pores end between the fifth and seventh nodes.

Basals variable, sometimes flattened and almost oblong, with wide upper angles and no downward extensions; sometimes very prominent and sharply pointed below. Radials usually four, with rather flattened surfaces, the second a syzygy. But there are several variations from this type. The rays divide three, or rarely four, times, giving about forty arms. These have about ninety joints beyond the last axillary, and are moderately smooth at the base; but their terminal portions become strongly serrate in the medio-dorsal line. Primary arms of six to ten (usually six or eight) distichals, the second or third of which is a syzygy. Secondary arms of ten to twenty-five (usually twelve or fourteen) palmars, the third of which is generally a syzygy. On the outer side of the ray there is sometimes, but rarely, another axillary after from fourteen to twenty-six joints, of which the second or third is a syzygy. There is generally a syzygy in the third brachial of the free arm; another between the seventh and eleventh brachials, and others at intervals of two to seventeen (usually four to eight) joints.

Some of the radial pinnules are large, with massive and cuboidal lower joints; but the four following pinnules are smaller, and the basal joints, though broad and somewhat flattened, are not as a rule specially massive, becoming comparatively inconspicuous after the palmar axillary. Their dorsal edge is sharp but not strongly serrate.

Disk well plated, both at the sides of and between the ambulacra. Brachial ambulacra but little above the arm-groove, and supported by large plates which soon pass into distinct side and covering plates on the pinnules.

Colour in spirit, greyish-white; "of a uniform dusky purple when fresh" (Moseley).

Locality.—Station 170A, July 14, 1874; near the Kermadec Islands; lat. 29° 45′ S., long. 178° 11′ W.; 630 fathoms; volcanic mud; bottom temperature, 39°·5 F. One specimen, but doubtful.

Station 214, February 10, 1875; off the Meangis Islands; lat. 4° 33′ N., long. 127° 6′ E.; 500 fathoms; blue mud; bottom temperature, 41°·8 F. Three (four?) specimens.

Remarks.—The individual figured on Pl. XLIV., which is very well preserved, was obtained at Station 214, off the Meangis Islands, together with two other examples which have the arms broken off at the syzygy in the second radials. A fourth mutilated individual, which had lost the disk and two rays, reached me in a bottle which also contained one specimen of *Metacrinus wyvillii*, and the label of Station 170A (near the Kermadecs). On the other hand, the figured specimen of *Metacrinus wyvillii* and also that of *Metacrinus varians* were together in a jar with the label of Station 214 (Meangis Islands). There is no question from other evidence that *Metacrinus wyvillii*, like *Pentacrinus naresianus*, occurs at both Stations; but I am a little uncertain about the single specimen of *Metacrinus varians*. For the two species, although distinctly

differentiated by Sir Wyville Thomson, and drawn on separate plates, do not seem to have been kept apart by him; and it is just possible that one individual of each may have been accidentally interchanged. An additional reason for believing that this doubtful example of *Metacrinus varians* really belongs to Station 214, and not to Station 170A, is that both the Cirripedes (*Scalpellum balanoides* and *Verruca nitida*) which are attached to the stem and cirri are recorded from Station 214, but not from Station 170A.

The four individuals of *Metacrinus varians* which the collection contains present a considerable amount of variation in several points of structure. One of them has a cirrus missing at one of the nodes on the stem, while two more are undeveloped at another node. The radials vary greatly, and present the following modifications, the second being a syzygy in every case:—

Three radials, the axillary a syzygy.
Four radials, the axillary simple (type).
Four radials, the axillary a syzygy.
Five radials, the axillary a syzygy.

In correspondence with this there is a great amount of variation in the size of the basal joints of the lowest pinnules. For there may be sometimes only one, and sometimes two of these appendages in each interradial space; and in the latter case the basal joints of one or both of them are much smaller than usual. The size of the distichal pinnules is also to some extent affected in the same way, the first one being frequently much smaller at the base than its successors.

Metacrinus varians is a species that stands very much by itself among those forms of *Metacrinus* which have normally but four radials. It is smaller and less robust than all the species previously described. From *Metacrinus angulatus* and *Metacrinus cingulatus* it differs in the absence of the markings on the sides of the stem-joints (Pl. XXXIX. figs. 3, 11; Pl. XLI. fig. 1; Pl. XLVII. fig. 6), and in the slightly shorter internodes; while in the types with smooth stems (*Metacrinus nobilis*, *Metacrinus murrayi*, and *Metacrinus superbus*) the internodes are considerably longer than in the more slender *Metacrinus varians*, and the grouping of the arm-divisions is different.

6. *Metacrinus moseleyi*, n. sp. (Pls. XLV., XLVI.).

Dimensions.

Length of tapering stem of young individual to twenty-third node,	138·00 mm.
Diameter of lower part of stem,	3·00 „
Longest cirrus (forty-five joints),	35·00 „
Diameter of calyx,	7·00 „
Length of the first radial pinnule (fifteen joints),	12·50 „
Length of first pinnule after palmar axillary (thirteen joints),	9·50 „

Stem slender and of a rounded pentagonal form, without lateral grooves. Usually seven internodal joints with scarcely crenulated edges and more or less marked horizontal ridges, which are especially prominent on the larger joints. The nodal joints are deeply hollowed by the cirrus-sockets, and have their angles slightly produced, so as to be lobate in form. The sockets extend but very slightly either on to the supra- or on to the infra-nodals. Cirri composed of forty to forty-five joints, the basal ones of which are not specially broad, while their successors are often a trifle longer than wide. Interarticular pores end at the sixth node.

Basals relatively very large and convex, pentagonal or almost oblong in form. (*N.B.*, the preceding description is based upon one individual only.) Radials very variable, sometimes only three or four, but usually five or even six, with the second and sometimes also the fourth a syzygy. Most of the rays divide three times, giving from thirty to forty arms, the longest unbroken ones of which consist of about fifty joints beyond the palmar axillary.

The dorsal surface of the skeleton is rather uneven, owing to the overlapping of the joints and the elevation of their distal edges, especially between the radials and the palmar axillaries. Primary arms of six to twelve (generally eight or ten) joints. Secondaries of seven to sixteen (usually ten or twelve) palmars. The third joint, but not unfrequently the fourth or fifth, after each axillary is generally a syzygy. The next syzygy in the free arms may be anywhere between the fifth and the thirtieth brachials, and others follow at very irregular intervals.

The radial pinnules vary in appearance according to their position, but the two lower joints are larger and more cuboidal than the rest, which are flattened laterally. The distichal and palmar pinnules are shorter than those on the radials, and gradually decrease in size. Their dorsal edge is sharpened, but the two lower joints are broad and expanded, as is also the case, though in a less degree, with the first pinnules on the free arms.

The disk is thickly covered with comparatively large plates, and the ambulacral skeleton is well developed. The brachial ambulacra are withdrawn into the narrow arm-groove, and but little plated independently of those of the pinnules, which have squarish side plates and large, rounded, covering plates.

Colour—a uniform dusky purple when fresh (Moseley), light grey when dry, almost white in spirit.

Locality.—Station 214, February 10, 1875; off the Meangis Islands; lat. 4° 33′ N., long. 127° 6′ W.; 500 fathoms; blue mud; bottom temperature, 41°·8 F. Two specimens.

Remarks—I have much pleasure in associating this pretty little species with the name of Prof. H. N. Moseley, F.R.S. Two specimens of it were obtained by the Challenger. One of them, represented on Pl. XLV., is evidently immature, as shown by the relatively large size of its basals, the length of its lower and middle cirrus-

joints, the frequent alternation of thick and thin joints in the stem, and the small size of its arms.

The larger specimen, figured on Pl. XLVI., appears to have met with an accident since it was drawn, for it came into my hands in the dry state, having lost its stem and basal ring. The characters of the rays and arms, however, are so essentially similar to those of the smaller individual that I have no hesitation in regarding the two as identical. The characters of the stem as a whole come nearest to those of *Metacrinus cingulatus* (compare Pl. XLI. figs. 1–3, and Pl. XLV. figs. 2–6). In both cases there is a continuous horizontal ridge round each of the mature internodal joints, but the articular faces are more lobate in *Metacrinus cingulatus* (Pl. XLI. fig. 3) than in *Metacrinus moseleyi* (Pl. XLV. fig. 2). The same is the case with the nodal joints which have more produced angles and consequently deeper cirrus-sockets in *Metacrinus moseleyi* than in the larger species. The characters of the cup, however, are quite different in the two types, that of *Metacrinus cingulatus* being extremely regular in the number of its radials, while in *Metacrinus moseleyi* there may be as few as three or as many as six. The only other species which resembles it in this respect is the large *Metacrinus rotundus*[1] from Japan, which has a smooth stem, with much longer internodes. The ten rays of the two individuals of *Metacrinus moseleyi* are constructed as follows:—

* One of three joints, the second and the axillary both syzygies.
* One of four joints, the second and the axillary both syzygies.
Three of five joints, the second a syzygy.
Two of five joints, the second and fourth syzygies.
One of six joints, the second a syzygy.
Two of six joints, the second and fourth syzygies.

The number of primitive joints in the ray, therefore, before the union of one or more pairs by syzygy, varies from five to eight, just as in other species of *Metacrinus*. The irregularity which distinguishes *Metacrinus moseleyi* thus lies rather in the mode of union of the primitive joints to form syzygial pairs than in any excess or defect of their number; though as a general rule there are either five (*Metacrinus angulatus*) or eight (*Metacrinus wyvillii*), and not both types in the same individual.

Two very anomalous instances which occur in the dry specimen are marked with an asterisk in the above list. In the first case the five primitive radials have become reduced to three, owing to the union of the last four into two syzygial pairs. In *Metacrinus angulatus* (Pl. XXXIX. fig. 1) the fourth primitive joint remains distinct from the axillary to which it is united by muscles, and bears the second pinnule. But on this abnormal ray of *Metacrinus moseleyi* these two joints are united by syzygy, and as the hypozygal of a syzygy never bears a pinnule, the natural condition would have

[1] See *Trans. Linn. Soc. Lond.* (Zool.), ser. 2, vol. ii. p. 437.

been the suppression of the second radial pinnule. As a matter of fact, however, it is present on the epizygal of the second radial, which thus bears two pinnules, one on each side. A similar instance of two pinnules on one joint also occurs in *Metacrinus cingulatus* (*ante*, p. 349), and recalls the condition of certain Palæocrinoids.

In the next ray to this one the fourth radial, which is a syzygial joint, is also the axillary; and although the first and second radial pinnules are present as usual, the axillary epizygal bears a pinnule in addition to the two primary arms. This pinnule, however, really belongs to one of the first distichal joints, which is much smaller than its fellow, and does not reach the outer edge of the arm at all. The consequence is that the first pinnule of the primary arm is borne by its second and not by its first joint, as is usually the case.

Apart from these irregularities, the larger dry specimen of *Metacrinus moseleyi* appears to be tolerably normal in its character. But the smaller individual is different. The stem tapers downwards, being only 3 mm. wide at the twenty-third node, but rather over 4 mm. at the twelfth node. The arms too are much malformed by commencing *Myzostoma*-cysts, either in the arm itself, or in the base of a pinnule, as shown in Pl. XLV. fig. 7.

7. *Metacrinus wyvillii*, n. sp. (Pl. XLVII. figs. 1–5; Pl. XLVIII.).

Dimensions.

Length of stem to thirty-fourth node,	27·00 cm.
Diameter of stem,	4·50 mm.
Longest cirrus (forty-five joints),	37·00 „
Diameter of calyx,	7·25 „
Length of arm (ninety joints beyond palmar axillary),	80·00 „
Length of first distichal pinnule (fifteen joints),	13·00 „
Length of first pinnule after palmar axillary (sixteen joints),	10·00 „

Stem pentagonal and moderately robust. Five to eight (generally seven) internodal joints, with more or less well defined horizontal ridges and slightly crenulated edges. Nodal joints bluntly stellate, with large facets of variable shape which take up their whole height, while the sockets extend on to both supra- and infra-nodal joints, especially the latter. Cirri of forty to forty-five very uniform joints, the lowest of which are but little wider than their successors. The lower cirri not specially shorter than the upper. Interarticular pores extend down to the sixth or seventh node.

Basals pentagonal, large and prominent, more or less sharply pointed below, sometimes being almost hexagonal. Radials usually six, with syzygies in the second and fourth. The rays, which are somewhat closely set, divide three or very rarely four times, giving nearly forty arms. These have about ninety joints above the palmar axillaries, and are almost quite smooth dorsally, except in the terminal third. Primary arms of

four to ten (usually eight or nine) distichals; twelve to twenty-six, but usually not more than sixteen, palmars in the secondary arms. Sometimes, but rarely, there is another axillary after some thirteen to twenty joints more. The third joint after each axillary is generally a syzygy. The following syzygies are distributed very irregularly in the free arms. The second is between the ninth and thirtieth brachials, usually about the twelfth or fifteenth; and the others at intervals of three to twenty (generally ten or twelve) joints.

The second and following radials bear pinnules of about a dozen moderately stout joints, the lowest of which are more or less massive and cuboidal, but vary considerably in size according to circumstances. The first distichal pinnule is nearly similar to those on the radials, but the following ones consist of more flattened joints, the lowest of which are much broader than their successors. This inequality is very marked in the pinnules which are borne on the palmars and the lower parts of the free arms, and also in a less degree in the smaller terminal pinnules. Brachial ambulacra but little above the narrow arm-groove, and only slightly plated between the origins of the pinnule-ambulacra, which soon begin to show well defined side plates.

Colour in spirit, greyish-white; a uniform dusky purple when fresh (Moseley).

Localities.—Station 170A, July 14, 1874; near the Kermadec Islands; lat. 29° 45′ S., long. 178° 11′ W.; 630 fathoms; volcanic mud; bottom temperature, 39°·5 F. Two specimens, one rather young.

Station 214, February 10, 1875; off the Meangis Islands; lat. 4° 33′ N., long. 127° 6′ W.; 500 fathoms; blue mud; bottom temperature, 41°·8 F. One good specimen; one mutilated individual, and two stem-fragments, one of which has the calyx and a portion of the arm-bases remaining.

Remarks.—This species is the only *Metacrinus* which is known with certainty to occur in the South as well as in the North Pacific. Although nearly resembling *Metacrinus moseleyi*, *Metacrinus costatus*, and *Metacrinus nodosus* in the length of the internodes of the stem and in the number of the distichal joints, it differs from them all in the other characters of the stem. The two last mentioned types have a somewhat sharply pentagonal stem, and the cirrus-facets are not so high as the nodal joints, the angles of which are much produced; while the sides of the joints are smooth or slightly tubercular (Pl. XLIX. fig. 3; Pl. LI. fig. 8). *Metacrinus wyvillii*, however, has a more rounded stem with horizontal ridges on the internodal joints; while the cirrus-facets occupy the whole height of the nodal joints (Pl. XLVII. figs. 1, 2). It is altogether a larger species than *Metacrinus moseleyi*, and has entirely different stem-joints, as is immediately evident upon comparison of the figures on Pls. XLV. and XLVII. respectively.

Another good character of *Metacrinus wyvillii*, which is more or less visible, however, in the species mentioned above, is the peculiar enlargement and flattening against the arm of the basal joints of the pinnules immediately above the radials, and the persistence

of this character to far out on the arms. It is well shown in some parts of fig. 1 on Pl. XLVIII.

It was on a proof copy of this plate that I found the MS. name *Metacrinus* in Sir Wyville's own handwriting; and I have therefore taken the opportunity of associating this elegant species with his memory. It is one of some importance on account of its occurrence at two such widely separated localities as the Kermadec Islands (Station 170A) in lat. 29° 45′ S., and the Meangis Islands (Station 214) in lat. 4° 33′ N. The two specimens obtained at the former Station are both of very considerable interest. The stem of the larger one, which is 25 cm. long, is broken at the thirty-sixth node, the internodes being shorter than in the more northern individuals, as seven joints are the exception and not the rule. As in so many other cases, this stem tapers gradually downwards, being almost 5 mm. wide immediately below the calyx, and less than 3 mm. at the lowest node, just above which the diminution in size is most rapid.

The other specimen obtained at Station 170A is a young individual, with a head not more than 55 mm. long, and less than sixty joints in the free arms. The attached portion of the stem, which is 185 mm. long, is a trifle over 3 mm. wide just below the basals, which are relatively very large and prominent. Its diameter decreases slightly to about the fifth node, and then slowly increases again till the sixteenth node, where the stem widens rather suddenly. It reaches 4 mm. at the last joint immediately below the twenty-seventh node. The ornamentation of this stem is less well defined than in the older specimen from the same locality. In fact there is a good deal of individual variation, some of the stems from Station 214 having very well defined horizontal ridges (Pl. XLVII. figs. 1, 2), while they are rather inconspicuous on the figured specimen (Pl. XLVIII. fig. 2).

One individual presents a curious amount of variation in the character of the rays. Three are normal, consisting of six joints, of which the second and fourth are syzygies; but on one of these the usual pinnule on the epizygal of the fourth brachial is missing, though that on the next joint is present. Another ray consists of seven joints, the fifth and sixth of which bear pinnules on the same side; while the fifth ray has eight joints with no pinnule on the sixth.

8. *Metacrinus costatus*, n. sp. (Pl. XLVII. fig. 13; Pl. XLIX.).

Dimensions.

Length of stem to the twenty-fourth node,	20·00 cm.
Diameter of stem,	3·75 mm.
Longest cirrus (forty-five joints),	32·00 ,,
Diameter of calyx,	6·50 ,,
Length of arm (one hundred joints beyond the palmar axillary),	70·00 ,,
Length of pinnule on first distichal (seventeen joints),	14·50 ,,
Length of first pinnule after palmar axillary (twenty joints),	11·00 ,,

Stem slender and pentagonal in outline, with slight re-entering angles. Generally seven or eight internodal joints with distinctly crenulated edges. Their relatively high sides are somewhat hollowed, and smooth or marked with faint ridges; while their angles are sharpened and a little produced outwards, so that the whole stem is traversed by five well defined interradial ridges.

The supra-nodals are but slightly incised, and the wide cirrus-facets do not reach the upper edges of the nodal joints. They likewise barely reach the lower edges, coming much nearer to them in some specimens than in others; and the infra-nodals are scarcely grooved, so that their re-entering angles are but little more marked than those of the other internodal joints.

Cirri composed of about forty joints, the first two of which are short and wide, while the eighth and a few following ones are sometimes a little longer than wide. The lower cirri do not seem to be specially shorter than the upper. Interarticular pores not visible below the tenth node.

The basals (in the only specimen possessing them) appear as small rhomboidal knobs with their pointed lower extremities resting on the interradial ridges at the top of the stem; but they extend laterally and meet their fellows in the re-entering angles between the first radials. The rays consist of six rounded joints, of which the second and fourth are syzygies, and are well separated laterally above the hypozygals of the second radials. They all divide three times, and there are generally additional axillaries on the two outermost of each set of four tertiary arms thus produced, so that the total number of arms reaches about sixty. They consist of about one hundred joints above the palmar axillaries, and are almost smooth in the medio-dorsal line till near the ends, which are slightly serrate.

The distichals, palmars, and lower brachials present a peculiarity which is much more marked in the baseless individual than in the more normal one. The pinnule-bearing side of each joint is slightly bent outwards above the pinnule-socket, and its edge is cut into several small teeth or spines. In addition to this the front edge of each joint and the corresponding part of the hinder edge of its successor are slightly raised on one or both sides, and are also more or less spinose. These characters are perhaps most distinctly marked upon the palmars, not being fully developed upon the distichals, and disappearing a little beyond the level of the tertiary axillaries. Six or eight joints in the primary arms; secondaries of eight to fourteen (usually ten or twelve) palmars. The next division (when present) may be from eight to twenty (generally twelve to sixteen) joints, and in one case there is another axillary after sixteen joints more. The third joint after each axillary is usually a syzygy. The next syzygy in the free arms may be anywhere between the sixth and thirtieth brachials, after which an interval of three to eighteen joints occurs between successive syzygies.

The pinnules on the radials and first distichals are large and massive, consisting of

eighteen or twenty joints, the lowest of which are cuboidal. The next few, though still very thick, are much flattened laterally and gradually diminish in width, with the lateral edges of the dorsal surface raised and thickened. The terminal part of the pinnule consists of much smaller joints, and is more or less distinctly serrate. In the pinnules of the third and the next following distichals the dorsal surface of the two or three thick basal joints is rather broad, but the following joints diminish rapidly both in breadth and in thickness. Beyond the distichal axillaries all the pinnule-joints are longer than wide, with the exception of the first two, which are much expanded, and this character is very marked in all the following pinnules till about the level of the fourth axillaries. Beyond this point the second and third pinnule-joints more nearly resemble their successors, though traces of the expansion of the first joint are visible for some distance farther.

The disk (so far as it is visible) is well protected by plates, both on its ventral surface and on its sides, right down to the hypozygal of the second brachial. The brachial ambulacra are but little above the narrow arm-groove, and are protected like those of the large lower pinnules by very irregular plates. The terminal pinnules have well defined and rather pointed side plates.

Colour—a uniform dusky purple when fresh (Moseley); in spirit, light brownish-white.

Locality.—Station 214, February 10, 1875; off the Meangis Islands; lat. 4° 33′ N., long. 127° 6′ E.; 500 fathoms; blue mud; bottom temperature, 41°·8 F. Two specimens, with *Myzostoma wyville-thomsoni*, von Graff.

Remarks.—This elegant little species is the smallest *Metacrinus* which I have yet seen, with the exception of *Metacrinus nodosus;* and it has many points of resemblance with that type, as will be explained later. Although the stem and cup are much less robust than in *Metacrinus wyvillii*, the number of arms is nearly half as large again as in that species, which rarely has an axillary beyond the palmars; while in *Metacrinus costatus* this is generally the case on four out of the eight tertiary arms, and there may be another axillary beyond the supra-palmar. The number of internodal joints is nearly the same in the two species, being rarely less than seven in *Metacrinus costatus*, though sometimes falling to five in *Metacrinus wyvillii*. But they are totally different in their form and external markings, as will be evident from a comparison of Pl. XLVII. figs. 1–4, and Pl. XLIX. figs. 3, 4. The nodal joints are also quite different in the two species. The cirrus-sockets of *Metacrinus wyvillii* (Pl. XLVII. figs. 1, 2) extend both upwards and downwards on to the supra- and infra-nodal joints beyond the articular facets, which occupy the whole height of the nodal joints. But this is far from being the case in *Metacrinus costatus;* and the nodal joints therefore are less deeply incised than in *Metacrinus wyvillii*, while their angles are much sharper and more produced outwards (Pl. XLIX. figs. 3, 5). There is also a good deal of difference between the pinnules of the two types. Both those on the radials and distichals of *Metacrinus wyvillii* and those

farther out on the arms are smaller than the corresponding pinnules of *Metacrinus costatus;* while the lowest pinnules are smaller, smoother, and have more rounded joints than the more massive but flattened pinnules of *Metacrinus costatus* with their serrate ends. On the other hand, the expansion of the two basal joints in the pinnules beyond the palmar axillary is more conspicuous in *Metacrinus wyvillii* than in *Metacrinus costatus,* and the remaining pinnule-joints are distinctly stouter than in that species.

There is a great amount of difference between the two specimens described above except in the characters of the stem, which are extremely constant, the number of internodal joints being almost invariably seven or eight. In the first place the basal plates of one individual are entirely absent; and each of the radials, which are slightly higher than in the other example, has a small downward projection in the middle of its base which rests directly on the top of one of the five ridges of the stem, as shown in Pl. XLIX. fig. 2. The basals of the other example are smaller than is usually the case in the genus; but their total absence, at any rate on the exterior of the calyx, is a most singular anomaly. One result of it is that the position of the cirri is interradial and not radial, as is generally the case; and presumably therefore the peripheral vessels from which the cirrus-vessels are supplied have a similar position. But these peripheral vessels are continuous above with the chambers of the chambered organ, which are normally set in the direction of the rays (Pl. XXIV. figs. 5-8; Pl. LVIII. figs. 1, 2; Pl. LXII.—*ch*); while the primary axial cords of the rays start from the interradial angles of the chambered organ (Pl. XXIV. fig. 7; Pl. LVIII. figs. 1, 3; Pl. LXII.—*ai*). If the mutual relation of these organs in this anomalous specimen were only known it would very probably throw much light upon the structure of the lower part of the calyx in those Palæocrinoids which have interradial cirri, such as *Heterocrinus, Iocrinus, Barycrinus,* and *Belemnocrinus florifer*. It is of course possible that the basals may be internal and concealed as in most Comatulæ and in some varieties of *Encrinus;* but I cannot help thinking that if they were really present at all the cirri would be placed radially as they usually are, and not interradially as is actually the case.

This baseless specimen presents the only irregularity in the number of the radials which occurs in the two individuals. The second radial is not traversed by a syzygy, as is invariably the case in all the other rays, though the second syzygy is in its normal position between the fifth and sixth joints of the primitive ray as in the ordinary type; but there is no additional joint between this syzygy and the axillary, so that the ray consists of six joints with the fifth a syzygy.

All the ten primary arms of this individual, however, consist of six joints, of which the third is traversed by a syzygy; while in the other specimen with a more normal calyx there is only one distichal series of this character, together with one of eight joints, of which the second is a syzygy; and the remaining six also consist of eight joints, but have a syzygy in the third. The later arm-divisions of the baseless specimen are

exceedingly regular, as it almost invariably has six arms above each distichal axillary arranged in the following order 2, 1 ; 1, 2. There are only two instances of an axillary occurring on one of the inner pair of the four tertiary arms ; while it is never absent on one of the outer pair. This regular arrangement recalls that already noticed in some species of *Pentacrinus*. But it is much less constant than in the more normal example with the regular calyx, and it is in this individual that the solitary instance of a fifth axillary occurs; while the peculiar development of spines on the lower arm-divisions is much more marked in the one without a base.

The pinnule-ambulacra vary considerably in their appearance according to their position, as will be seen by a comparison of Pl. XLVII. fig. 13 and Pl. XLIX. figs. 6, 7 ; and it is only on the later pinnules of the arm that the side and covering plates come to be distinctly differentiated. The peculiar mode of development of the side plates on some of the larger pinnules has been already described (*ante*, p. 82). The same character is also visible in *Metacrinus wyvillii* and *Metacrinus nodosus* (Pl. LI. fig. 12), though to a less extent.

The occasional enlargement of some of the arm-joints appears to indicate that an encysting *Myzostoma* had commenced operations. This is probably the *Myzostoma pentacrini* of von Graff.[1] It "does not produce real cysts upon the arms of its host, but only swellings of several (three to six) joints, which gradually disappear." It was found in abundance on *Pentacrinus alternicirrus* from the same Station (214) as *Metacrinus costatus*; whereas the free *Myzostoma wyville-thomsoni* which was attached to the disk of the latter species occupied a similar position on the disk of *Metacrinus angulatus* from Station 192, off the Ki Islands.

9. *Metacrinus nodosus*, n. sp. (Pls. L., LI.).

Dimensions.

Length of stem to seventeenth node,	14·00 cm.
Diameter of stem,	3·00 mm.
Longest cirrus (forty-five joints),	35·00 ,,
Diameter of calyx,	6·00 ,,
Diameter of disk,	12·50 ,,
Length of pinnule on fourth radial (fourteen joints),	13·00 ,,
Length of pinnule on first joint after palmar axillary (thirteen joints),	9·00 ,,

Stem slender and sharply pentagonal. Eight or nine internodal joints with distinctly crenulated edges and a faint tubercle in the middle of each side. Nodals, especially in the young stem, produced outwards at the angles between the wide cirrus-facets which do not reach either edge. Supra- and infra-nodal joints both somewhat modified. Cirri

[1] Zool. Chall. Exp., part xxvii. p. 63, 1884.

of about forty joints, some of which (after the short and wide ones at the base) are longer than broad. The dorsal edge of the middle joints is slightly serrate, but the later ones become almost smooth. Interarticular pores end about the ninth node.

Basals pentagonal and forming a closed ring, but very convex in the centre, so as to appear like rhomboidal knobs resting on the interradial ridges of the stem. Radials six, very convex, the second and fourth syzygies. Rays well separated laterally, and divide four times. Arms twelve or more to the ray, slightly serrate in the medio-dorsal line, especially in the lower divisions. Primaries of six or eight (rarely ten) joints; secondaries of eight to fourteen palmars; tertiaries of sixteen to twenty-eight joints. The third joint after each axillary is a syzygy, and the next syzygy in the free arms is anywhere between the tenth and twenty-fourth joints; after which the syzygies follow at intervals of five to fourteen joints.

The radial pinnules, especially the first one, mostly have wide and massive basal joints with thickened edges; but the middle joints are more compressed and the terminal ones slender. The distichal pinnules are also stout and composed of large joints; but the following ones consist of compressed and more elongated joints, the first two of which are considerably wider than the rest until some little way beyond the last axillary.

The disk is covered with numerous small plates, which are much smaller and more closely set in the anal interradius than elsewhere. Brachial ambulacra above the arm-grooves, and protected by irregular plates from which the covering plates and large pointed side plates are developed on the pinnules.

Colour—of a uniform dusky purple when fresh (Moseley); greyish-white in spirit.

Locality.—Station 170A, July 14, 1874; near the Kermadec Islands; lat. 29° 45′ S., long. 178° 11′ W.; 630 fathoms; volcanic mud; bottom temperature, 39°·5 F.

Remarks.—Three examples of this elegant little species seem to have been obtained by the Challenger. One of them is quite young (Pl. LI. fig. 1), while the other two were in a much mutilated condition. The dissected calyx figured on Pl. L. figs. 5–18 appears to belong to the fragment represented on fig. 1 of the same Plate. It is certainly not the same as that of which the disk is shown in fig. 2. This last and a few detached arms have served as the basis of the foregoing description. The only species with which *Metacrinus nodosus* is liable to be confused is the little *Metacrinus costatus* from off the Meangis Islands (Station 214). For *Metacrinus wyvillii*, which also has six radials and about the same number of internodal joints, is altogether much larger and more robust. But it has a smaller number of arms than either *Metacrinus costatus* or *Metacrinus nodosus*. The difference between these two last lies chiefly in the characters of the stem, both of them having twelve or more arms on the ray, owing to the presence of axillaries on the outermost of each set of four tertiary arms, as well as on some of the inner ones occasionally. The pinnules are generally similar in the two types, and the peculiar

modification of the lower arm-joints above the pinnule-sockets, which was noticed in *Metacrinus costatus*, is also visible in *Metacrinus nodosus*, though to a less extent.

There is a good deal of difference, however, between the stems of the two species. While the normal number of internodal joints in *Metacrinus costatus* is seven or eight, that of *Metacrinus nodosus* is eight or nine, and they are very regularly marked by a faint tubercle in the middle of each side, which is flat and scarcely hollowed at all (Pl. LI. fig. 8). In *Metacrinus costatus*, on the other hand, the sides of this stem are almost smooth, or only marked by a few occasional horizontal ridges, while they are distinctly hollowed between the prominent angles (Pl. XLIX. figs. 3, 4), so that the stem appears to be traversed along its whole length by five rather sharp interradial ridges. In the uppermost and growing part of the stem these ridges are much more prominent on the closely set nodal joints than on the thin internodals which separate them. But as the latter increase in thickness their interradial angles are also enlarged, so that those on the nodal joints are not specially prominent. This character is also visible in *Metacrinus nodosus*, both in the stem-joints of young individuals (Pl. LI. figs. 6, 7) and in the growing part of the stem of the more mature specimen. But there are no strong ridges developed at the angles of the internodes, as is the case in *Metacrinus costatus*, so that those of the nodal joints are always more or less prominent (Pl. L. fig. 4; Pl. LI. fig. 8).

The side plates on the pinnule-ambulacra of *Metacrinus nodosus* are relatively large and pointed (Pl. LI. figs. 11, 12). They are developed in the same style as those of *Metacrinus costatus* (Pl. XLVII. fig. 13) from the somewhat irregular plates of the brachial ambulacra, which are not so bifid as in *Metacrinus angulatus* (Pl. XXXIX. fig. 13) or in *Metacrinus varians* (Pl. XLVII. figs. 11, 12).

The young individual of *Metacrinus nodosus*, which is represented in Pl. LI. fig. 1, has a slightly tapering stem containing sixteen nodes, at the eighth of which one cirrus-socket is undeveloped. The characters of the young stem-joints, which are shown in figs. 2–7, have been noticed already (*ante*, p. 291).

Of the four rays remaining in this specimen only one is normal, *i.e.*, composed of six joints, of which the second and fourth are syzygies. In one case the fifth joint is the axillary, and in another the fourth, which is at the same time a syzygial joint like the second; while in another ray the fourth radial is not a syzygy, though the fifth is axillary and united to it somewhat closely, so as to give almost the appearance of a syzygy.[1] But the presence of a pinnule on the fourth joint shows conclusively that it cannot be the hypozygal of a syzygy, as its homologue is in the next ray.

This specimen is so young that the palmar axillaries are with difficulty distinguished from the ordinary joints of the secondary arms; and in some cases at any rate they seem to have been farther from the distichal axillaries than is usual in the larger indi-

[1] A little too much has been made of this resemblance to a syzygy in the right hand side of the figure.

vidual. Attached to a stem-fragment which was brought up with these individuals were a small Ophiuran and a young Turbinolian coral (Pl. LI. fig. 8).

10. *Metacrinus interruptus*, n. sp. (Pl. LII.).

Dimensions.

Length of stem to nineteenth node,	21·00 cm.
Diameter of stem,	4·25 mm.
Longest cirrus (forty-five joints),	43·00 „
Diameter of calyx,	8·00 „
Length of arm (one hundred and thirty joints beyond the palmar axillary),	105·00 „
Length of pinnule on second radial (twenty joints),	22·00 „
Length of pinnule on third distichal (eighteen joints),	16·00 „
Length of pinnule on first joint beyond the palmar axillary (eighteen joints),	11·00 „

Description of an Individual,—Stem moderately slender, with a sharply pentagonal outline. Ten or eleven internodal joints with but slightly crenulated edges. Their sides are somewhat hollowed, and marked by tolerably distinct horizontal ridges. These are interrupted at the angles which generally bear very faint tubercles. The supra-nodal joints are slightly incised, but the cirrus-sockets terminate in thickened rims distinctly above the lower edge of the nodal joint. Its syzygial face, like that of the infra-nodal, is thus regularly pentagonal, as is its outline when seen from above, although the upper surface is distinctly lobate. Cirri composed of forty to forty-five very uniform joints, the lowest but little wider than their successors, few or none of which are longer than wide. The cirri are longest between the ninth and twelfth nodes; and the inter-articular pores end at the eleventh node.

Basals widely pentagonal, but not specially prominent. Radials six, with syzygies in the second and fourth. The joints are somewhat sharply rounded and relatively narrow, so that the rays are widely separated above the hypozygal of the second joint. They all divide three times; but there is a fourth axillary in two cases, so that the total number of arms is forty-two. These have about one hundred and thirty joints above the palmar axillary, the basal ones almost quite smooth, and the later joints only with very slightly raised distal edges. Primary arms of eight (rarely ten) distichals, and secondaries of twelve to sixteen or eighteen palmars. In two cases there is a third division after ten and twelve joints respectively. The third joint after each axillary is a syzygy. The next syzygy in the free arms may be anywhere between the ninth and sixtieth brachials; after which an interval of six to fifteen joints occurs between successive syzygies.

The radial pinnules are very large and massive, the first one especially so. It consists of twenty or twenty-two joints, the first six of which are very stout and almost cubical in appearance, the second being the largest, and the terminal joints slightly serrate,

The following pinnules gradually decrease in size and their joints become more flattened, the two lowest retaining a certain amount of preponderance, being often much broader than their successors. Beyond the distichal axillary, however, this is almost entirely lost, the pinnules tapering gradually and symmetrically from the basal joints, which are not specially distinguished in any way.

The disk (so far as it is visible) is covered with numerous small plates which are not, however, set perfectly close to one another. Brachial ambulacra but little above the arm-grooves, and bordered by somewhat forked plates from which the large side plates of the pinnule-ambulacra are soon developed.

Colour in spirit, greyish-white, with a tinge of brown at the tips of the cirri, arms, and pinnules.

Locality.—Station 209, January 22, 1875; lat. 10° 14′ N., long. 123° 54′ E.; 95 fathoms; blue mud; bottom temperature, 71° F. One specimen.

Remarks.—This species is readily distinguished from the three preceding ones in the same group by the greater length of the internodes in the stem. Their component joints (Pl. LII. fig. 3) are altogether different from the lobate joints of *Metacrinus costatus* (Pl. XLIX. fig. 4) and of *Metacrinus nodosus* (Pl. LI. fig. 10), having the same pentagonal form and horizontal ridges as *Metacrinus wyvillii* (Pl. XLVII. fig. 4). The nodal and infra-nodal joints, however, are entirely different from those of this type, in which the infra-nodals are distinctly incised by the cirrus-sockets, so that their syzygial surface is lobate (Pl. XLVII. fig. 3) and not pentagonal as in *Metacrinus interruptus*. Another character in which this species differs very markedly from the three previously considered is the small size of the basal joints on the palmar and lower brachial pinnules.

The type to which on the whole *Metacrinus interruptus* appears to be most closely allied is the as yet undescribed specimen dredged by the "Vega" at a depth of 65 fathoms in the Bay of Yedo. By the kind permission of Prof. S. Lovén, who was good enough to send me some fragments of its stem, and also to allow my friend Mr. W. Percy Sladen to examine it on my behalf, I am able to say that it appears to be totally different from *Metacrinus interruptus*. The stem-joints that I have seen have a smaller diameter and a greater height both relatively and absolutely than those of that species; and they are not provided with horizontal ridges, but only with faint tubercles at the angles, and still less distinct ones at the sides. In the character of the nodal joints, however, and in the absence of any extension of the cirrus-socket down on to the infra-nodals, the two types are very closely similar, as they are in the length of the internodes. There seem to be several other points of difference between *Metacrinus interruptus* and the "Vega" specimen, such, for example, as the length of the primary arms and the characters of the pinnules. These will doubtless be explained more fully when the "Vega" Crinoids are described; and I have therefore done no more than assign to the Japanese form a place

in the tabular key to the species which embraces all the types of this genus that have yet been discovered.

The individual described above is the only specimen of any kind of Crinoid which was obtained at Station 209; and it has fortunately suffered much less injury than many of the larger types dredged by the Challenger. I did not succeed in finding any *Myzostoma* upon it; but a *Scalpellum* is attached to its stem, and several individuals of *Verruca* to the cirri, on one of which a small *Avicula* was fixed by its byssus.

11. *Metacrinus tuberosus*, n. sp. (Pl. LIII. figs. 1–6).

Three species (*Metacrinus angulatus*, *Metacrinus nobilis*, *Metacrinus cingulatus*), represented by "about a dozen individuals,"[1] were dredged by the Challenger at Station 192, off the Ki Islands. Together with these there came up a fragment of a stem which I cannot refer to either of these species, nor to any other *Metacrinus* yet known. It presents a curious combination of certain features which are characteristic of the stems of *Metacrinus angulatus*, *Metacrinus costatus*, and *Metacrinus nobilis* respectively, three very distinct species from widely separated localities on different sides of the equator (Ki, Meangis, and Kermadec Islands). I have no hesitation in regarding it as belonging to another species of the genus, although the characters of its calyx are as yet unknown.

It cannot belong to a *Pentacrinus* on account of the upward extension of the cirrus-sockets on to the supra-nodal joints (Pl. LIII. fig. 2), a character which is eminently distinctive of *Metacrinus*.

The fragment consisted of five complete internodes, one of which was sacrificed to anatomical purposes, so that only four are shown in the figure (Pl. LIII. fig. 1). Each internode consists of seven slightly crenulated joints. The five middle ones are as usual different from those immediately above and below the nodes. They are sharply pentagonal in form, with a somewhat prominent tubercle in the middle of each side (Pl. LIII. figs. 4, 6); while the angles are sharp and slightly produced outwards beyond the ends of the petaloid areas, as is to some extent the case in *Metacrinus angulatus* and *Metacrinus costatus* (Pl. XXXIX. figs. 3, 8, 10, 11; Pl. XLIX. figs. 3, 4). This is still more evident in the nodal joints (Pl. LIII. fig. 3) as it also is in the other two species (Pl. XXXIX. figs. 3–5; Pl. XLIX. fig. 5), and more distinctly in *Metacrinus nodosus*, the internodes of which are not specially produced at the angles (Pl. LI. figs. 8–10). The consequence is that the stem of *Metacrinus tuberosus*, like that of *Metacrinus angulatus* and *Metacrinus costatus*, is traversed by prominent interradial ridges (Pl. XXXVIII.; Pl. XXXIX. figs. 3, 11; Pl. XLIX. figs. 1, 3; Pl. LIII. figs. 1, 6). The nodal joints have somewhat deeply hollowed cirrus-sockets which have relatively wide facets, and encroach both on the supra- (Pl. LIII. fig. 2) and on the infra-nodal

[1] See R. v. Willemoes-Suhm, Briefe von der Challenger-Expedition, No. iv., *Zeitschr. f. wiss. Zool.*, Bd. xxvi. p. liii., 1876.

joints (Pl. LIII. fig. 5); so that their re-entering angles are deeper than those of the remaining internodal joints (Pl. LIII. fig. 4). On both of these, but especially on the infra-nodal (fig. 5), the single tubercles at the sides of the joint are more or less double, and enlarged into a horizontal ridge. A peculiarity of somewhat the same kind occurs in *Metacrinus costatus* (Pl. XLIX. fig. 3).

The cirri are about 35 mm. long, and closely resemble those of other species of the genus. They consist of some forty uniformly squarish joints, the basal ones of which are not much wider than their successors, though projecting a little beyond them on the dorsal side. There is no trace of interarticular pores, so that this fragment cannot have come from near the top of the stem.

Thus, then, the peculiarities of this stem-fragment are sufficiently characteristic to indicate that it belongs to a different species of *Metacrinus* from any of those described above. In the prominence of the angles of the nodal joints, and in the presence of tubercles along the sides of the internodes, it resembles *Metacrinus nodosus* (Pl. LI. fig. 8). But in the sharpness of the ridges formed by the angles of the internodes it approaches *Metacrinus angulatus* (Pl. XXXIX. figs. 3, 11) and *Metacrinus costatus* (Pl. XLIX. figs. 1, 2). As the composition of its calyx is unknown, no place can be assigned to *Metacrinus tuberosus* in the tabular scheme of the genus. If there be four radials it would come near *Metacrinus angulatus*, though the internodes are shorter than in this type; but if the number of radials be six, its place would be next to *Metacrinus costatus* and *Metacrinus nodosus*, both of which it resembles in the length of its internodes.

Clinging to this stem by its long arms was the pluteus-larva of an Ophiurid, with three arm plates beyond the disk.

Locality.—Station 192, September 26, 1874; in the Arafura Sea, near the Ki Islands; lat. 5° 49′ S., long. 132° 14′ E.; 140 fathoms; blue mud. A stem-fragment only.

Family Comatulidæ, d'Orbigny, 1852.

Genus *Thaumatocrinus*, P. H. Carpenter, 1883.

Thaumatocrinus, P. H. Carpenter, Phil. Trans., part iii., 1883, p. 919, pl. 71.

Definition.—Calyx composed of a centro-dorsal, basals, radials, and primary interradials, the latter resting on the basals and so separating the radials laterally. That on the anal side bears a short jointed appendage. Mouth central, and protected by five large oral plates which occupy the greater part of the disk, and are separated from the calyx interradials by two or three rows of small irregular plates. Five arms only.

Remarks.—Although this very singular genus is a true *Comatula, i.e.*, provided with a centro-dorsal plate or cirrus-bearing top stem-joint which separates it from the remainder

of the larval stem, I have preferred to describe it in the same part of the Crinoid Report as the Stalked Crinoids. For it is only among certain of the Palæocrinoidea that we meet with characters which are at all like the more striking peculiarities of *Thaumatocrinus*.

There can, I think, be no doubt that the large and comparatively dense oral plates are not in a state of resorption as they are in other Comatulæ of the same size; for they have all the appearance of being permanent structures. *Thaumatocrinus* is therefore the only *Comatula* yet known in which the oral plates of the larva persist through life as in *Hyocrinus* and *Rhizocrinus*.

Another striking peculiarity is presented by the closed ring of relatively large basals which have remained in their primitive position upon the exterior of the calyx and have not undergone transformation into a rosette, as is the case in most other Comatulæ. The only other recent type in which the basals remain visible on the exterior of the calyx is the curious genus *Atelecrinus*;[1] and here they are very small in proportion to the radials. This is probably also the case in the Cretaceous species which is mentioned by Schlüter[2] as provided with a closed basal ring.

Both the persistence of the basals and the considerable development of the orals are characters which, either singly or combined, would cause the type to be regarded as one of no little interest; but they are altogether cast into the shade by the other peculiarities of the calyx, viz., the complete separation of the radials by relatively large interradial plates and the presence of the anal appendage. It has been shown elsewhere[3] that in the separation of its radials laterally *Thaumatocrinus* is permanently in the condition of a Crinoid larva at a very early period of Pentacrinoid life, and that this condition is characteristic of certain Palæocrinoids belonging to the family Rhodocrinidæ. Some genera, such as the Lower Silurian *Reteocrinus* and *Xenocrinus*, have the radials separated by what Messrs. Wachsmuth and Springer[4] describe as an "interradial series resting directly upon the basals, consisting of a very large number of minute pieces of irregular form, and without definite arrangement." A similar development of small irregular plates between the rays occur in many Neocrinoids, both stalked and free, but the interradial series always commence at the level of the second or third radials, and are completely separated from the basals by the ring of united first radials. This is well seen in *Pentacrinus asterius* (Pl. XIII. fig. 1) and in the fossil *Extracrinus*.

In other genera of the Rhodocrinidæ such as *Rhodocrinus* itself, *Thylacocrinus*, and others forming the section *Rhodocrinites*, the first radials are separated not by small and irregular plates as in *Reteocrinus*, but by large plates, one resting on a basal in each interradius; and this is the condition of *Thaumatocrinus* (Pl. LVI. figs. 1–4). While

[1] *Bull. Mus. Comp. Zoöl.*, vol. ix., No. 4, 1881, p. 16, pl. i. figs. 1–7.
[2] *Zeitschr. d. deutsch. geol. Gesellsch.*, Jahrg. 1878, p. 66.
[3] *Phil. Trans.*, 1883, part iii, pp. 923–925; and *ante*, pp. 39, 40.
[4] Revision, part ii. p. 192.

resembling the *Rhodocrinites* in having five large plates separating the radials, *Thaumatocrinus* differs from them and from most Palæocrinoids in the absence of any higher series of calicular interradial plates resting upon the first series which separate the radials.

Except on the anal side the primary interradial plates of *Thaumatocrinus* end simply in a free rounded edge at the margin of the disk (Pl. LVI. figs. 1–3, 5), which is doubtless due to the simplicity of the arms; for these become free almost at once, and are not connected laterally by much perisome in which higher orders of radials could be supported. But in the presence of the anal appendage on the azygous interradial (Pl. LVI. figs. 2, 4, 5) *Thaumatocrinus* bears a remarkable resemblance to *Reteocrinus* as understood by Wachsmuth and Springer, and to the *Xenocrinus* of S. A. Miller; while the appendage has an even closer resemblance to the so called "anal series" of *Onychocrinus* and *Taxocrinus*, the lowest plate of which rests, not on a basal, but on the upper angles of the two first radials.

There can, I think, be no reasonable doubt that the anal appendage of *Thaumatocrinus*, although free laterally, is homologous with the vertical series of plates in the anal interradius of *Reteocrinus* and *Xenocrinus*, *Onychocrinus* and *Taxocrinus*. But owing to the small size of *Thaumatocrinus* and the simplicity of its rays the anal appendage is free; whereas in the Palæocrinoids it is united to the more or less branching rays by the general series of minute irregular plates which occupy the anal interradius and pass gradually upwards into those of the so called vault.

It is difficult to consider the existence of interradials and of the anal appendage of *Thaumatocrinus* as instances of atavism, for no known Neocrinoid presents any similar characters, and it is a long way back from a recent *Comatula* to a Palæozoic Crinoid. The reappearance of these characters in such a specialised type as a *Comatula* is consequently not a little surprising. Associated with them we find the distinctly embryonic characters of persistent basal and oral plates, the latter occurring in no other *Comatula*, together with the simplicity of the undivided arms.

Thaumatocrinus renovatus, P. H. Carpenter, 1883 (Pl. LVI. figs. 1–5).

Description of an Individual.—The total width of the calyx across the disk is barely 2 mm.; and the height of the centro-dorsal and radials together is about the same. The former (Pl. LVI. figs. 1–4) is rounded below, with its central canal completely closed up, so that it must have been detached for some little time from the remainder of the stem. The bases of half a dozen cirri are attached to it, and there are pits for the reception of two or three more. In the largest stump which is preserved (Pl. LVI. figs. 1, 3) the first two joints are quite short, as is usually the case in all cirri; but the third reaches a length of 1·5 mm., so that the cirri must have been very like those of

some species of *Eudiocrinus* which have a succession of very long joints following the short basal ones.

The basals are almost trapezoidal, much wider below than above, and in contact with one another by their truncated lower angles (Pl. LVI. figs. 1, 2). The middle of the lower edge of each is slightly tubercular. On their narrow upper edges rest the interradials, which are oblong and a little higher than wide. Four of them terminate in a free edge at the margin of the disk where they are in contact with the lowest anambulacral plates. But that on the anal side bears a small tapering appendage of four or five joints, the last of which seems to end freely (Pl. LVI. figs. 2, 4, 5). The radials are larger than the interradials, and somewhat strongly arched. There is a muscular articulation between them and the first brachials; but the union of these to the next joints appears to be by ligament only. The arm-joints are long, slender, and cylindrical. One arm seems to be broken at the syzygy in the sixth brachial; while another has a syzygy in the fourth and again in the eighth brachial. The second brachial bears the first pinnule, which is on the right side in three arms and on the left in the other two. The pinnules are very delicate, and composed of long slender joints.

The central portion of the disk is occupied by five relatively large oral plates which stand up around the peristome (Pl. LVI. fig. 5); while between them and the margin are two or three irregular rows of small anambulacral plates, some of them extending up on to the lower part of the long anal tube. The brachial ambulacra are not plated, however, and lie in the arm-grooves, close down between the muscles, but with no traces of sacculi.

Colour in spirit, dirty white.

Locality.—Station 158, March 7, 1874; lat. 50° 1′ S., long. 123° 4′ E.; 1800 fathoms; Globigerina ooze; bottom temperature, 33°·5 F. One specimen much mutilated and probably young.

XIII.—BATHYMETRICAL DISTRIBUTION AND STATION LISTS.

STATION LIST OF THE STALKED CRINOIDS WHICH HAVE BEEN OBTAINED BY THE VARIOUS BRITISH EXPEDITIONS FOR DEEP-SEA EXPLORATION BETWEEN THE YEARS 1868 AND 1880.

This list also contains the names of the rarer Comatulæ, when dredged at a Station where Stalked Crinoids occurred. The presence of the more common genera (*Antedon* and *Actinometra*) is also indicated, though without any attempt to go into specific details.

H.M.S. "LIGHTNING," 1868.

STATION 12. Lat. 59° 36′ N., long. 7° 20′ W.; 530 fathoms; Globigerina ooze; bottom temperature, 47°·3 F.

Rhizocrinus lofotensis.

STATION 16. Lat. 61° 2′ N., long. 12° 4′ W.; 650 fathoms; Globigerina ooze,

Rhizocrinus lofotensis. Also at Station 12; and the "Knight Errant," 1880, Stations 5 and 6; the Challenger, Stations 24A, 122C, and 323 (*fide* C. W. T.). Also at several Stations in the Gulf Stream, the Caribbean Sea, and off the New England coast.

H.M.S. "PORCUPINE," 1869.

STATION 37. Lat. 47° 38′ N., long. 12° 8′ W.; 2435 fathoms; Globigerina ooze; bottom temperature, 36°·5 F.

Bathycrinus gracilis. Also the "Talisman" (1883), off the Morocco coast—"Par le travers du cap Ghir et du cap Noun à 120 milles environ de la côte," 2000–2300 metres (about 1200 fathoms).

STATION 42. Lat. 49° 12′ N., long. 12° 52′ W.; 862 fathoms; ooze with sand and shells; bottom temperature, 39°·7 F.

Rhizocrinus rawsoni.

STATION 43. Lat. 50° 1′ N., long. 12° 26′ W.; 1207 fathoms; Globigerina ooze; bottom temperature, 37°·7 F.

Rhizocrinus rawsoni. Also at Station 42; the Challenger, Station 76; and at various Stations in the Caribbean Sea. Also the "Travailleur" (1882)—"1900m. de profondeur sur les côtes du Maroc, par le travers du cap Blanc;" and the "Talisman" (1883)—"Par le travers du cap Ghir et du cap Noun à 120 milles environ de la côte," 2000–2300 metres (about 1200 fathoms).

H.M.S. "PORCUPINE," 1870.

STATION 17. Lat. 39° 42′ N., long. 9° 43′ W.; 1095 fathoms; ooze; bottom temperature, 39°·7 F.

Pentacrinus wyville-thomsoni. Also the "Talisman" (1883); off the Morocco coast; and again off Rochefort; lat. 45° 59′ N., long. 6° 29′ W. of Paris; 1500 metres (800 fathoms).

H.M.S. "KNIGHT ERRANT," 1880.

STATION 5. Lat. 59° 26′ N., long. 7° 19′ W.; 515 fathoms; mud; bottom temperature, 45°·4 F.

Rhizocrinus lofotensis.

STATION 6. Lat. 59° 37′ N., long. 7° 19° W.; 530 fathoms; grey mud; bottom temperature, 46°·5 F.

Rhizocrinus lofotensis.

H.M.S. CHALLENGER, 1873–76.

STATION 24A. March 25, 1873; off Culebra Island; lat. 18° 43′ N., long. 65° 5′ W.; 625 fathoms; Pteropod ooze.

Rhizocrinus lofotensis. Also Stations 122c and 323 (*fide* C. W. T.); the "Lightning" (1868), Stations 12 and 16; and the "Knight Errant" (1880), Stations 5 and 6. Several Stations in the Gulf Stream, the Caribbean Sea, and off the New England coast.

STATION 76. July 3, 1873; south of Terceira (Azores); lat. 38° 11′ N., long. 27° 9′ W.; 900 fathoms; Pteropod ooze; bottom temperature, 40° F.

Rhizocrinus rawsoni. Also the "Porcupine" (1869), Stations 42 and 43. Also the "Travailleur" (1882), the "Talisman" (1883), and at several Stations in the Caribbean Sea.

STATION 106. August 25, 1873; lat. 1° 47′ N., long. 24° 26′ W.; 1850 fathoms; Globigerina ooze; bottom temperature, 36°·6 F.

Bathycrinus campbellianus.

Hyocrinus bethellianus (stem-fragments, *fide* C. W. T.). Also at Station 147; and Station 223?

STATION 122. September 10, 1873; off Barra Grande; lat. 9° 5′ S., long. 34° 50′ W.; 350 fathoms; red mud.

Pentacrinus maclearanus.

Atelecrinus balanoides. Also at several Stations in the Caribbean Sea.

STATION 122c. September 10, 1873; off Barra Grande; lat. 9° 10′ S., long. 34° 49′ W.; 400 fathoms; red mud.

Rhizocrinus lofotensis. Also Stations 24A and 323 (*fide* C. W. T.); the "Lightning" (1868), Stations 12 and 16; and the "Knight Errant" (1880), Stations 5 and 6. Several Stations in the Gulf Stream, the Caribbean Sea, and off the New England coast.

STATION 146. December 29, 1873; lat. 46° 46′ S., long. 45° 31′ E.; 1375 fathoms; Globigerina ooze; bottom temperature, 36°·6 F.

Bathycrinus aldrichianus. Also at Station 147; and "at at least six or seven Stations in the Atlantic and the Southern Ocean."

STATION 147. December 30, 1873; lat. 46° 16′ S., long. 48° 27′ E.; 1600 fathoms; Diatom ooze; bottom temperature, 34°·2 F.

Bathycrinus aldrichianus. Also at Station 146.

Hyocrinus bethellianus. Also at Stations 106 and 223 (*fide* C. W. T.).

Antedon (three species).

Promachocrinus abyssorum. Also at Station 158.

STATION 158. March 7, 1874; lat. 50° 1′ S., long. 123° 4′ E.; 1800 fathoms; Globigerina ooze; bottom temperature, 33°·5 F.

Thaumatocrinus renovatus.
Promachocrinus abyssorum. Also at Station 147.

STATION 170A. July 14, 1874; near the Kermadec Islands; lat. 29° 45′ S., long. 178° 11′ W.; 630 fathoms; volcanic mud; bottom temperature, 39°·5 F.

Pentacrinus naresianus. Also at Stations 171, 175, 210 (?), 214.
Metacrinus nodosus
Metacrinus wyvillii. Also at Station 214.
Antedon (six species).

STATION 171. July 15, 1874; off Raoul Island; lat. 28° 33′ S., long. 177° 50′ W.; 600 fathoms; hard ground; bottom temperature, 39°·5 F.

Pentacrinus alternicirrus. Also at Stations 210 (?), 214.
Pentacrinus naresianus. Also at Stations 170A, 175, 210 (?), 214.

STATION 175. August 12, 1874; near Kandavu, Fiji; lat. 19° 2′ S., long. 177° 10′ E.; 1350 fathoms; Globigerina ooze; bottom temperature, 36° F.

Pentacrinus naresianus. Also at Stations 170A, 171, 210 (?), 214.
Antedon (three species).

STATION 192. September 26, 1874; near the Ki Islands; lat. 5° 49′ S., long. 132° 14′ E.; 140 fathoms; blue mud.

Metacrinus angulatus.
Metacrinus cingulatus.
Metacrinus murrayi (?).
Metacrinus nobilis.
Metacrinus tuberosus.
Antedon (twelve species).
Actinometra (one species).

STATION 209. January 22, 1875; lat. 10° 14′ N., long. 123° 54′ E.; 95 fathoms; blue mud; bottom temperature, 71° F.

Metacrinus interruptus.

STATION 210. January 25, 1875; off the Panglao and Siquijor Islands; lat. 9° 26′ N., long. 123° 45′ E.; 375 fathoms; blue mud; bottom temperature, 54°·1 F.

Pentacrinus alternicirrus (?). Also at Stations 171 and 214.
Pentacrinus naresianus (?). Also at Stations 170A, 171, 175, and 214.
Metacrinus murrayi (?).
Antedon (two species).

STATION 214. February 10, 1875; off the Meangis Islands; lat. 4° 33′ N., long. 127° 6′ E.; 500 fathoms; blue mud; bottom temperature, 41°·8 F.

Pentacrinus alternicirrus. Also at Stations 171 and 210 (?).
Pentacrinus naresianus. Also at Stations 170A, 171, 175, and 210 (?).
Metacrinus costatus.
Metacrinus moseleyi.
Metacrinus murrayi (?).
Metacrinus varians.
Metacrinus wyvillii. Also at Station 170A.
Antedon (six species).
Promachocrinus naresi.

STATION 223. March 19, 1875; lat. 5° 31′ N., long. 145° 13′ E.; 2325 fathoms; Globigerina ooze; bottom temperature, 35°·5 F.

Hyocrinus bethellianus, young (*fide* C. W. T.). Also at Stations 106 (C. W. T.) and 147.

STATION 235. June 4, 1875; lat. 34° 7′ N., long. 138° 0′ E.; 565 fathoms; green mud; bottom temperature, 38°·1 F.

Pentacrinus (?) *mollis.*
Eudiocrinus japonicus.

STATION 323. February 28, 1876; lat. 35° 39′ S., long. 50° 47′ W.; 1900 fathoms; blue mud; bottom temperature, 33°·1 F.

Rhizocrinus lofotensis (*fide* C. W. T.). Also the "Lightning" (1868), Stations 12 and 16; the "Knight Errant" (1880), Stations 5 and 6; and the Challenger, Stations 24A and 122C. Also at several Stations in the Gulf Stream, the Caribbean Sea, and off the New England coast.

STATION LIST OF THE STALKED CRINOIDS WHICH HAVE BEEN OBTAINED BY THE VARIOUS AMERICAN EXPEDITIONS FOR DEEP-SEA EXPLORATION (MOSTLY UNDER THE DIRECTION OF MR. ALEXANDER AGASSIZ) BETWEEN THE YEARS 1867 AND 1880.

The presence of Comatulæ is noticed as in the previous list; but the occurrence of a species at several Stations is not, as a rule, recorded more than once.

SS. "CORWIN," 1867.

No. 2. May 24, 1867; 1·6 miles from Chorrera, Cuba; 270 fathoms.
Pentacrinus decorus (stem only ?).

SS. "BIBB," 1868–69.

May 9, 1868; off the Samboes; 237 fathoms.

May 11, 1868; off Sand Key; 248 and 306 fathoms.
Rhizocrinus lofotensis. Also off Havana, Barbados, Grenada, and Grenadines. Dredged by the "Lightning," the Challenger, and the "Knight Errant."

March 4, 1869; off Cojima, near Havana; 450 fathoms.
Rhizocrinus lofotensis.
Atelecrinus cubensis.
Antedon.

March 10, 1869; off Double-headed Shot Keys; 315 and 471 (?) fathoms.
Pentacrinus decorus (stem only ?).

SS. "HASSLER," 1871–72.

December 30, 1871. Off Sandy Bay, Barbados; 100 fathoms.
Rhizocrinus rawsoni. Also off Havana, Montserrat, Guadeloupe, Dominica, Martinique, and Panama. Dredged in the East Atlantic by the "Porcupine," Challenger, "Talisman," and "Travailleur."

SS. "BLAKE," 1878–80.

Cruise of 1877–78.

STATION 21. Off Bahia Honda, Cuba; lat. 23° 2′ N., long. 83° 13′ W.; 287 fathoms.
Pentacrinus decorus. Also off Havana, Montserrat, St. Vincent Barbados, Kingston, and Saba Island.

STATION 22. Off Bahia Honda, Cuba; lat. 23° 1′ N., long. 83° 14′ W.; 100 fathoms; bottom temperature, 71° F.

Holopus rangi. Also off Barbados (Rawson) and Montserrat.

STATION 29. Lat. 24° 36′ N., long. 84° 5′ W.; 955 fathoms; bottom temperature, 39½° F.

Rhizocrinus lofotensis.

STATION 32. Lat. 23° 32′ N., long. 88° 5′ W.; 95 fathoms.

Rhizocrinus rawsoni.

Antedon.

STATION 35. Lat. 23° 52′ N., long. 88° 58′ W.; 804 fathoms; bottom temperature, 40½° F.

Rhizocrinus lofotensis.

STATION 43. Lat 24° 8′ N., long. 82° 51′ W.; 339 fathoms.

Rhizocrinus lofotensis.

Atelecrinus balanoides.

STATION 44. Lat. 25° 33′ N., long. 84° 35′ W.; 539 fathoms; bottom temperature, 39½° F.

Rhizocrinus lofotensis.

STATION 56. Off Havana; lat. 22° 9′ N., long. 82° 21′ 30″ W.; 175 fathoms.

Rhizocrinus lofotensis.

Pentacrinus decorus.

Pentacrinus milleri. Also off Santiago de Cuba, Barbados, Guadeloupe, Martinique, St. Lucia, St. Vincent, Montserrat, Saba Island.

Antedon.

STATION 57. Off Havana; lat. 22° 9′ 15″ N., long. 82° 21′ W.; 177 fathoms.

Pentacrinus decorus.

Antedon.

Cruise of 1878–79.

STATION 100. Off Morro Light; 250 and 400 fathoms.

Pentacrinus decorus.

Pentacrinus milleri.

STATION 101. Off Morro Light; 175 and 250 fathoms.

Pentacrinus decorus.
Pentacrinus milleri.
Antedon.

STATION 155. Off Montserrat; 88 fathoms; bottom temperature, 69° F.

Rhizocrinus rawsoni.
Pentacrinus decorus.
Antedon.
Actinometra.

STATION 156. Off Montserrat; 88 fathoms; bottom temperature, 69° F.

Pentacrinus decorus.
Antedon.
Actinometra.

STATION 157. Off Montserrat; 120 fathoms.

Holopus rangi. Also off Barbados (Rawson) and Bahia Honda (Cuba).
Pentacrinus asterius. Also off Saba Island.
Pentacrinus blakei. Also off Barbados and Martinique.
Pentacrinus decorus.
Pentacrinus milleri.
Antedon.
Actinometra.

STATION 166. Off Guadeloupe; 150 fathoms; hard bottom; bottom temperature, 59¾° F.

Rhizocrinus rawsoni.

STATION 171. Off Guadeloupe; 183 fathoms; bottom temperature, 55½° F.

Pentacrinus milleri.
Actinometra.

STATION 177. Off Dominica; 118 fathoms; fine sand and broken shells; bottom temperature, 65° F.

Rhizocrinus rawsoni.
Actinometra.

STATION 193. Off Martinique; 169 fathoms; fine sand, dark mud, and shells; bottom temperature, 51° F.

Pentacrinus milleri.
Antedon.
Actinometra.

STATION 209. Off Martinique; 189 fathoms; bottom temperature, 49¾° F.
Pentacrinus blakei. Also off Barbados and Montserrat.

STATION 211. Off Martinique; 357 fathoms; fine yellow sand and broken shells.
Rhizocrinus rawsoni.

STATION 218. Off St. Lucia; 164 fathoms; bottom temperature, 56° F.
Pentacrinus milleri.

STATION 233. Off Milligan's Key, St. Vincent; 174 fathoms; rocky bottom; bottom temperature, 49½° F.
Pentacrinus decorus.
Antedon.

STATION 238. Off Grenadines; 127 fathoms; fine coral sand; bottom temperature, 56° F.
Rhizocrinus lofotensis.

STATION 248. Off Grenada; 161 fathoms; fine grey ooze; bottom temperature, 53½° F.
Rhizocrinus lofotensis.
Actinometra.

STATION 259. Off Grenada; 159 fathoms; bottom temperature, 53½° F.
Rhizocrinus lofotensis.
Antedon.
Actinometra.

STATION 269. Off St. Vincent; 124 fathoms; bottom temperature, 57½° F.
Pentacrinus decorus.
Pentacrinus milleri.
Antedon.
Actinometra.

STATION 273. Off Barbados; 103 fathoms; coral and broken shell, yellow; bottom temperature, 59½° F.
Rhizocrinus rawsoni.
Actinometra.

STATION 274. Off Barbados; 209 fathoms; fine sand and ooze; bottom temperature, 53½° F.
Rhizocrinus lofotensis.
Pentacrinus milleri.

STATION 277. Off Barbados; 106 fathoms; hard rocky bottom; bottom temperature, 58° F.

Rhizocrinus rawsoni.
Actinometra.

STATION 280. Off Barbados; 221 fathoms; Globigerina sand; bottom temperature, 50½° F.

Pentacrinus mülleri.

STATION 283. Off Barbados; 237 fathoms; hard bottom; bottom temperature, 49° F.

Pentacrinus mülleri.
Antedon.

STATION 290. Off Barbados; 73 fathoms; coarse coral sand and broken shells; bottom temperature, 70¾° F.

Rhizocrinus rawsoni.
Antedon.
Actinometra.

STATION 291. Off Barbados; 200 fathoms; flat calcareous stones; bottom temperature, 49¾° F.

Pentacrinus blakei. Also off Martinique and Montserrat.
Pentacrinus mülleri.

STATION 295. Off Barbados; 180 fathoms; hard bottom; bottom temperature, 50¾° F.

Pentacrinus blakei.
Pentacrinus mülleri.

STATION 296. Off Barbados; 84 fathoms; hard bottom; bottom temperature, 61½° F.

Rhizocrinus rawsoni.
Pentacrinus decorus.
Pentacrinus mülleri.
Actinometra.

STATION 297. Off Barbados; 123 fathoms; calcareous stones; bottom temperature, 56½° F.

Rhizocrinus rawsoni.
Antedon.
Actinometra.

STATION 298. Off Barbados; 120 fathoms; broken shells and coral; bottom temperature, 61° F.

Pentacrinus decorus.
Antedon.
Actinometra.

STATION V. Santiago de Cuba; 288 fathoms

Pentacrinus decorus.

Cruise of 1879–80.

Off Kingston (Jamaica); 100 fathoms.

Pentacrinus decorus.

STATION 306. Lat. 41° 32′ N., long. 65° 55′ W.; 524 fathoms.

Rhizocrinus lofotensis.

OTHER LOCALITIES IN THE CARIBBEAN SEA, THE GULF OF MEXICO, AND IN THE ATLANTIC OCEAN.

U. S. Fish Commission, 1882. No. 1124, S.S.E. off Nantucket; 640 fathoms.

Rhizocrinus lofotensis.

SS. "Investigator," Captain E. Cole.

Saba Bank; 200 fathoms.

Rhizocrinus rawsoni.

Saba Island; 320 fathoms.

Pentacrinus asterius.
Pentacrinus decorus.

Between Saba and Eustatius Islands; 531 fathoms.

Pentacrinus mülleri.
Pentacrinus decorus.

Fifteen miles N.E. from Panama; 300 fathoms.

Rhizocrinus rawsoni.

South side of Porto Rico; 667 fathoms.

Pentacrinus decorus.

Dr. Schramm, Guadeloupe.

Pentacrinus asterius.

W. Stimpson, Cuba.

Pentacrinus decorus.

Sir Rawson Rawson, Barbados.

A. *Pentacrinus müllери.*
A. *Pentacrinus decorus.*
A. *Antedon.*
A. *Actinometra.*
B. *Holopus rangi.*

A List of the known Living Species of Stalked Crinoids, showing their Bathymetrical and Geographical Distribution.

Explanation of the Letters used.

A. Species discovered by the "Blake."
B. Previously known species collected by the "Blake" and the U. S. Coast Survey Expeditions.
C. Species discovered by the Challenger.
D. Previously known species collected by the Challenger.
E. Species discovered by the ships of the Eastern Telegraph Company.
F. Species discovered by Dr. L. Döderlein.
I. Previously known species collected by the telegraph steamer "Investigator," Captain E. Cole.
J. Previously known species collected by the "Josephine" (Swedish).
N. Species discovered by the "Vöringen" (Norwegian).
P. Species discovered by the "Porcupine."
Q. Previously known species collected by the "Lightning," "Porcupine," and "Knight Errant."
R. Previously known species collected for Sir Rawson Rawson.
T. Previously known species collected by the "Talisman" and "Travailleur" (French).
V. Species discovered by the "Vega" (Swedish).
X. Species discovered by Mr. Damon's collectors.
Y. Previously known species obtained by Mr. Damon's collectors.

	How obtained.	Range in Depth.	Principal Localities.
		Fathoms.	
HOLOPIDÆ, Roemer,	...	...	... ...
Holopus, d'Orb.,	...	...	... ...
H. rangi, d'Orb.,	B. R.	100–120	Caribbean Islands.
HYOCRINIDÆ, Carpenter,	...	...	... ...
Hyocrinus, Wyv. Thoms.,	...	...	... ...
H. bethellianus, Wyv. Thoms.,	C.	1600–1850 2325?	Mid-Atlantic, Station 106 (stem-fragments); Southern Ocean, Station 147; East Pacific, Station 223 (young?).
BOURGUETICRINIDÆ, de Loriol,	...	...	... ...
Bathycrinus, Wyv. Thoms.,	...	...	... ...
B. aldrichianus, Wyv. Thoms.,	C.	1375–1600	Southern Ocean, Stations 146, 147.
B. campbellianus, Carp.,	C.	1850	Mid-Atlantic, Station 106.
B. carpenteri, Dan. & Kor.,	N.	1050–1495	North-East Atlantic.
B. gracilis, Wyv. Thoms.,	P. T.	1280–2435	East Atlantic.
Rhizocrinus, Sars,	...	...	... ...
R. lofotensis, Sars,	B. D. J. Q.	80–955 1900?	Lofoten Islands; Faroe Channel; North-East Atlantic; Josephine Bank. Atlantic Coast of U.S. (Northern States); Straits of Florida; Caribbean Islands; South-West Atlantic, Station 122c and Station 323 (?).
R. rawsoni, Pourt.,	B. D. I. P. T.	73–1280	East Atlantic, Station 76; Straits of Florida; Caribbean Islands; Yucatan Bank; off Panama.
PENTACRINIDÆ, d'Orb.,	...	...	... ...
Pentacrinus, Miller,	...	...	... ...
P. alternicirrus, Carp.,	C.	500–600 375?	Pacific—near the Kermadecs, Station 171; and near the Meangis Islands, Station 214; off the Panglao and Siquijor Islands, Station 210 (?).
P. asterius, Linn.,	B. I. Y.	80–320	Caribbean Islands.
P. blakei, Carp.,	A.	120–200	Caribbean Islands.
P. decorus, Wyv. Thoms.,	B. I. X.	84–667	Caribbean Islands; Straits of Florida.

	How obtained.	Range in Depth.	Principal Localities.
		Fathoms.	
P. macleayanus, Wyv. Thoms.,	C.	350	South-West Atlantic, Station 122.
P. mollis, Carp.,	C.	565	North-West Pacific.
P. milleri, Oerst.,	B. I. R. Y.	84–531	Caribbean Islands; Straits of Florida.
P. naresianus, Carp.,	C.	500–1350 375?	Pacific—near the Kermadecs, Stations 170, 170A, 171; near Fiji, Station 175; and near the Meangis Islands, Station 214; off the Panglao and Siquijor Islands, Station 210 (?).
P. wyville-thomsoni, Jeffr.,	P. T.	740–1095	East Atlantic.
Metacrinus, Carp.,	...	...	... ...
M. angulatus, Carp.,	C.	140	Ki Islands, Station 192.
M. cingulatus, Carp.,	C.	140	Ki Islands, Station 192.
M. costatus, Carp.,	C.	500	Pacific, near the Meangis Islands, Station 294.
M. interruptus, Carp.,	C.	95	Philippine Islands, Station 209.
M. moseleyi, Carp.,	C.	500	Pacific, near the Meangis Islands, Station 214.
M. murrayi, Carp.,	C.	?	Western Pacific, or East Indian Archipelago.
M. nobilis, Carp.,	C.	140	Ki Islands, Station 192.
M. nodosus, Carp.,	C.	630	Pacific, near the Kermadecs, Station 170A.
M. rotundus, Carp.,	F.	70	Japan.
M. stewarti, Carp.,	E.	?	Singapore.
M. superbus, Carp.,	E.	?	Singapore.
M. tuberosus, Carp.,	C.	140	Ki Islands, Station 192.
M. varians, Carp.,	C.	500	Pacific, near the Meangis Islands, Station 214.
M. wyvillii, Carp.,	C.	500–630	Pacific—near the Kermadecs, Station 170A; near the Meangis Islands, Station 214.
Metacrinus, sp.,	V.	65	Japan.

Analysis of the above List.

Genus.	Number of Living Species.	"Porcupine."		Challenger.		"Blake."	
		New Species.	Species previously known.	New Species.	Species previously known.	New Species.	Species previously known.
Holopus,	1	...	...	...	...	...	1
Hyocrinus,	1	...	...	1	...	...	...
Bathycrinus,	4	1	...	2	...	...	...
Rhizocrinus,	2	1	1[1]	...	2	...	2
Pentacrinus,	9	1	...	4	...	1	3
Metacrinus,	15	...	...	11	...	...	...
Total known species,	32	3	1	18	2	1	6

It thus appears that (1) the cruises of the "Porcupine" in 1869–70 added one genus and three species to the three genera and five species previously known. (2) More than half of the number (thirty-two) of known species, including two new genera, were discovered by the Challenger. (3) More than 65 per cent. of the known species have been discovered by H.M.SS. "Porcupine" and Challenger; while the small number of genera known before 1869 has been doubled by the explorations of these two ships.

BATHYMETRICAL TABLES.

A Roman numeral opposite the name of a species shows that it also occurs in one of the other Tables.

TABLE I.—Species found at depths down to 100 fathoms.

Holopus rangi, II.
Rhizocrinus lofotensis, II., III., IV., V., VI. (?)
rawsoni, II., III., V., VI.
Pentacrinus asterius,[2] II., III.
decorus, II., III., IV.
Pentacrinus müllerì, II., III., IV.
Metacrinus interruptus.
rotundus.
Metacrinus sp. (Vega).

[1] Dredged by the "Lightning" in 1868, if not by the "Porcupine" in 1869. See *Proc. Roy. Soc. Edin.*, vol. xii. p. 356, 1884.

[2] Two specimens in the Bristol Museum are believed to have been taken at a depth of 50 to 80 fathoms (Austin); and the earliest known examples must certainly have been obtained at depths above 100 fathoms.

TABLE II.—Species found at depths between 100 and 250 fathoms.

Holopus rangi, I.	*Pentacrinus müllerí*, I., III., IV.
Rhizocrinus lofotensis, I., III., IV., V., VI. (?)	*Metacrinus angulatus.*
rawsoni, I., III., V., VI.	*cingulatus.*
Pentacrinus asterius, I., III.	*murrayi* (?).[1]
blakei.	*nobilis.*
decorus, I., III., IV.	*tuberosus.*

TABLE III.—Species found at depths between 250 and 500 fathoms.

Rhizocrinus lofotensis, I., II., IV., V., VI. (?)	*Pentacrinus naresianus*, VI.
rawsoni, I., II., V., VI.	*Metacrinus costatus.*
Pentacrinus alternicirrus, IV.	*moseleyi.*
asterius, I., II.	*murrayi* (?).[2]
decorus, I., II., IV.	*varians.*
maclearanus.	*wyvillii*, IV.
müllerí, I., II., IV.	

TABLE IV.—Species found at depths between 500 and 700 fathoms.

Rhizocrinus lofotensis, I., II., III., V., VI. (?)	*Pentacrinus müllerí*, I., II., III.
Pentacrinus alternicirrus, III.	*Metacrinus nodosus.*
decorus, I., II., III.	*wyvillii*, III.
mollis.	

TABLE V.—Species found at depths between 700 and 1200 fathoms.

Rhizocrinus lofotensis, I., II., III., IV., VI. (?)	*Bathycrinus carpenteri*, VI.
rawsoni, I., II., III.	*Pentacrinus wyville-thomsoni.*

TABLE VI.—Species found at depths between 1200 and 2000 fathoms.

Rhizocrinus lofotensis (?),[3] I., II., III., IV., V.	*Bathycrinus carpenteri*, V.
rawsoni, I., II., III., V.	*gracilis*, VII.
Bathycrinus aldrichianus.	*Hyocrinus bethellianus*, VII.
campbellianus.	*Pentacrinus naresianus*, III.

TABLE VII.—Species found at depths between 2000 and 2500 fathoms.

Bathycrinus gracilis, VI.	*Hyocrinus bethellianus* (?),[4] VI.

[1] If at Station 192; 140 fathoms.
[2] If at Stations 210 or 214; 375 and 500 fathoms.
[3] If at Station 323; 1900 fathoms.
[4] If at Station 223; 2325 fathoms.

Summary.

A.

I. 9 species found at depths down to 100 fathoms.
II. 11 (or 12) species found between 100 and 250 fathoms.
III. 13 (or 12) species found between 250 and 500 fathoms.
IV. 7 species found between 500 and 700 fathoms.
V. 4 species found between 700 and 1200 fathoms.
VI. 8 species found between 1200 and 2000 fathoms.
VII. 2 species found between 2000 and 2500 fathoms.

B.

1	species descending from	Table	I. to II.
1	„	„	I. to III.
2	„	„	I. to IV.
2	„	„	I. to VI.
2	„	„	III. to IV.
1	„	„	III. to VI.
1	„	„	V. to VI.
1	„	„	VI. to VII.

C.

9	species found at depths down to	100	fathoms.
14 (or 15)	„	250	„
22	„	500	„

To these we may fairly add the two species of *Metacrinus* found near Singapore by one of the ships of the Eastern Telegraph Company, as it is improbable that they were living at a greater depth than 500 fathoms.

It has been the custom of late years, more especially since the discovery of *Pentacrinus wyville-thomsoni* and *Bathycrinus gracilis* by the "Porcupine," at 1095 and 2435 fathoms respectively, to regard the Stalked Crinoids as pre-eminently abyssal types, and as probably forming "rather an important element in the abyssal fauna."[1] It will be apparent, however, from the statistics given above, that subsequent researches have not altogether confirmed these views. If, as Mr. Agassiz has done in his Report on the Echinoidea,[2] we take the limit of the continental line at 500 fathoms, it appears from Summary C, that twenty-four of the thirty-two recent species of Stalked Crinoids, or 75 per cent., occur within this limit; while nine of these, living at depths less than 100 fathoms, may be called littoral.

Although numerous and extensive dredgings have been carried on in the abyssal zone (*i.e.*, at depths below 500 fathoms) during the last fifteen years, Stalked Crinoids have

[1] The Depths of the Sea, p. 455.

[2] Zool. Chall. Exp., part ix. p. 222.

only been found at thirty-four Stations. These have yielded thirteen species, representing five different genera, as shown in the following lists.

Table showing the Number of Times that Stalked Crinoids have been Dredged in the Abyssal Zone.

Rhizocrinus alone,	15	
Pentacrinus alone,	8	
Bathycrinus alone,	6	
Hyocrinus alone,	1	= 34
Bathycrinus and *Hyocrinus*,	2	
Pentacrinus and *Metacrinus*,	1	
Rhizocrinus and *Bathycrinus*,	1	

N.B.—All the doubtful cases are included in this list.

Table showing the Species of Stalked Crinoids which occur in the Abyssal Zone.

Genus.	Species confined to the Abyssal Zone.	Continental Species occurring in the Abyssal Zone.	Littoral Species occurring in the Abyssal Zone.
Bathycrinus,	*aldrichianus.* *campbellianus.* *carpenteri.* *gracilis.*	... ...	... ...
Hyocrinus,	*bethellianus.*	... ...	... ...
Pentacrinus,	*mollis.* *wyville-thomsoni.*	*alternicirrus.* *naresianus*	... ...
Metacrinus,	*nodosus.*	*wyvillii.*	... ...
Rhizocrinus,	... ...	... ...	*lofotensis.* *rawsoni.*
	8	3	2

Thus, then, thirteen species have been found in the abyssal zone, two of which are also littoral, while three are continental. The two former both belong to the genus *Rhizocrinus*, of which no exclusively abyssal species are known; though it has been met with at sixteen out of the thirty-four Stations in the abyssal zone. It is well represented in the Lower Tertiaries, and perhaps ranges back to the Cretaceous period, when its larger ally *Bourgueticrinus* was so abundant.

Pentacrinus has been found at nine Stations where the depth exceeded 500 fathoms; and two of its four abyssal species are also continental. But on the other hand, *Bathycrinus*, which occurs in the Atlantic at nine abyssal Stations between lat. 65° N. and 46° S., has never been found at a less depth than 1050 fathoms; while it embraces four out of the eight species which are peculiar to the abyssal zone.

No fossil *Bathycrinus* is known, however, and the genus has no special affinities except with *Rhizocrinus*, of which it may almost be said to be the "benthal"[1] representative. Of the four remaining abyssal species, one is the sole representative of the remarkable genus *Hyocrinus*, and has only been met with at 1600 fathoms and still greater depths. Like the Comatulid genus *Thaumatocrinus*, which occurs at 1800 fathoms in the Southern Ocean, it has certain strong points of resemblance to the Palæocrinoids.

Pentacrinus ranges back to the Trias and *Rhizocrinus* to the Eocene or Upper Cretaceous. But they are both abundant at depths of less than 100 fathoms, *Pentacrinus* occurring in the Pacific and in the East Indian Archipelago, as well as in the Atlantic and among the Caribbean Islands; while *Rhizocrinus*, though limited to the eastern hemisphere, ranges through over 100° of latitude.

In spite, therefore, of the existence of a few characteristic abyssal types, it is somewhat of an exaggeration to speak of the Stalked Crinoids as a group "on the verge of extinction," of which a few survivors may occasionally be discovered in the deeper parts of the great ocean basins.

[1] Dr. Gwyn Jeffreys has suggested that this word be employed to denote depths exceeding 1000 fathoms. See his address to the Biological Section at the Plymouth Meeting of the British Association, 1877, p. 79.

APPENDIX.

NOTE A.

(Pages 2, 157, and 168.)

On the Homologies of the Crinoidal Calyx in the other Echinoderms.

The relations of the plates which enter into the composition of the calyx of a Crinoid to those constituting the apical system of an Urchin or a Starfish are still the subject of much discussion.

The apical system of an Urchin, as described by Lovén,[1] consists typically of a dorsocentral plate enclosed within two rings of five plates each. The plates of the proximal ring (genitals, *Auct.*) are interradial in position, while those of the outer ring (oculars) are radially situated. Believing that the dorsocentral is represented in the Pentacrinoid larva of a *Comatula* by the terminal plate at the base of the stem,[2] I have suggested that the basals of the Pentacrinoid are homologous with the so called genitals of an Urchin; while the ocular plates of the latter correspond to the radials of the Crinoid. So far as the basals and radials are concerned this view is fundamentally the same as that previously expressed by Lovén and Agassiz, allowance being made for the difference between their terminology and that employed by myself; so that the homology between the basals and radials of a Crinoid and the two rows of plates surrounding the dorsocentral of an Urchin has been pretty generally accepted.

Dr. R. Hoernes,[3] however, objects to this homology (which he associates with my name) on the ground that the resemblance should be most marked in the geologically oldest types, "was keineswegs der Fall ist, da gerade der Scheitelapparat der Palæchinoiden durchaus nicht an die Basis-Entwickelung der Crinoiden-Kelches sich anschliesst." This objection may be answered in two ways. 1. Lovén[4] says that the general formula of the apical system of Echinoidea "has remained, more or less altered, but always recognisable, from Palæozoic to recent time." 2. The positive fact that the basals and radials of

[1] Études sur les Échinoïdées, *K. Svensk. Vetensk. Akad. Handl.*, Bd. xi., 1874, No. 7, p. 65.

[2] *Quart. Journ. Micr. Sci.*, 1878, vol. xviii., N. S., p. 374.

[3] Elemente der Palæontologie (Palæozoologie), Leipzig, 1884, p. 130.

[4] On Pourtalesia, a genus of Echinoidea, *K. Svensk. Vetensk. Akad. Handl.*, Bd. xix., 1883, No. 7, p. 62.

the Crinoid larva have precisely the same relation to the vaso-peritoneal system as the corresponding plates (genitals and oculars) of an Urchin is a strong reason for not laying too much stress upon the negative evidence of a confessedly imperfect palæontological record.[1]

In one respect it is somewhat unfortunate that the Urchins should have been selected as affording the typical apical system of the Echinozoa, with which that of a Crinoid could be compared. For their apical system is primitively a comparatively simple one; whereas many Crinoids have a ring of plates immediately beneath the basals which are unrepresented in the Urchins, though present in many Ophiurids and Asterids.

In his endeavour to find an early Crinoidal form with a calyx of the same simple description as the apical system of an Urchin, Professor Lovén[2] was led to select the genus *Cyathocrinus* (*Poteriocrinus*); and he proposed the following homologies between the two types:—

1. Dorsocentral of Urchin = the five under-basals of *Cyathocrinus* (the basals of J. Müller).
2. Genitals of Urchin = the five basals of *Cyathocrinus* (the parabasals of J. Müller).
3. Ocular plates of Urchin = radials of *Cyathocrinus*.

The two last of these propositions have been generally, but not universally, accepted. As regards the first, however, I am sorry to say that I have found myself unable to agree with Professor Lovén.

I pointed out six years ago[3] that the under-basals of *Cyathocrinus* constitute an element in the calyx which is by no means so constant in its occurrence as it should be, were it a fundamental part of the apical system and homologous with the dorsocentral of an Urchin or Starfish. Under-basals are present in *Encrinus*, *Extracrinus*, and *Marsupites* among the Neocrinoids, and in *Cyathocrinus*, *Poteriocrinus*, *Rhodocrinus*, and a large number of allied genera among the Palæocrinoids; while they are absent in *Apiocrinus*, *Pentacrinus*, *Actinocrinus*, *Platycrinus*, and in many other less known genera. When present, there are generally five distinct plates, resting on the upper stem-joint; and this fact, together with the want of constancy in their occurrence, caused me to suspect that they could not be collectively homologous to the primitively single dorsocentral plate of an Urchin or Starfish, as supposed by Lovén. I was therefore led to seek for the homologue of this last in the terminal plate at the end of the stem of the Pentacrinoid larva, which occupies the same position with regard to the right peritoneal tube as the dorsocentral of a larval Urchin or Starfish. This suggestion has been accepted by Lütken and by Sladen, as I have pointed out above (p. 168), though it is altogether ignored by Lovén. But no serious arguments have been yet brought forward against it by other authors who have discussed the question; while, on the other hand,

[1] Dr. Hoernes does not appear to have gone into the subject very deeply. I have nowhere suggested that the radials of an Urchin are homologous with the basals of a Crinoid; nor that the madreporite of *Clypeaster* is comparable to the centro-dorsal of *Comatula* and to the central plate in the calyx of *Marsupites*. Nevertheless Hoernes thinks fit to express his dissent from these views, which have originated with no one but himself, and he entirely misses the real point at issue.

[2] Études, *loc. cit.*, p. 80.

[3] *Quart. Journ. Micr. Sci.*, 1878, vol. xviii., N. S., pp. 358–361.

several recent researches have supplied further cogent reasons for rejecting the homologies which Lovén seeks to establish between the dorsocentral of an Urchin or Starfish and the under-basals of a dicyclic Crinoid.

Six years ago the numerous modifications of the apical system which are presented by Asterids and Ophiurids had received comparatively little attention; and I was therefore led to regard the under-basals of *Encrinus*, *Extracrinus*, and of the Palæozoic Crinoids as "additional elements which occur in the apical system of some Crinoids, while they are unrepresented in other members of the order and in the other Echinoderms."[1] Four years later, however,[2] I was able to show that the apical system of the young *Amphiura squamata*, which had been recently described by Ludwig,[3] corresponded precisely with that of *Marsupites*, the type which was first selected by Lovén for comparison with *Salenia*. Both in *Amphiura* and in *Marsupites* there is a central abactinal plate representing the dorsocentral of an Urchin. Next to this come, not the interradial plates corresponding to the genitals of an Urchin and the basals of *Cyathocrinus*, as Lovén formerly supposed,[4] but a ring of radially situated plates which correspond to the under-basals of *Cyathocrinus*, but are not represented at all in the apical system of an Urchin, as at present known. Outside these come the interradial basals (genitals) and then the radials (oculars). Ludwig discovered that the latter remain on the disk of *Amphiura*, and are not carried away from it by the growing arms as had been generally supposed.

Having discovered, as I believed, the homologues of the under-basals of a Crinoid in a larval Ophiurid, I naturally began to seek for them in the adult members of the class; and it soon appeared that they were represented in the rosette of primary plates which occupies the centre of the disk in certain species of *Ophioglypha*, *Ophioceramis*, *Ophiomusium*, and *Ophiozona*.[5] At the same time two important discoveries bearing on this question were made by Sladen.[6] (1) The radial plates of the larval Asterid remain on the disk, like those of the Ophiurid, and are not carried outwards by the growing arms, as was formerly supposed. (2) In the late larvæ of *Zoroaster fulgens*, *Asterina gibbosa*, *Asterias rubens*, *Asterias glacialis*, and other species, the so called genital plates (=basals of a Crinoid) are separated from the dorsocentral by a ring of radial plates which occupy exactly the same position as the under-basals of *Marsupites*, and the corresponding plates in the Ophiurids mentioned

[1] *Quart. Journ. Micr. Sci.*, 1878, vol. xviii., N. S., p. 374.

[2] *Ibid.*, 1882, vol. xxii. p. 380.

[3] Zur Entwicklungsgeschichte des Ophiurenskelettes, *Zeitschr. f. wiss. Zool.*, Bd. xxxvi. 1882, pp. 181–200, Tafn. x., xi.

[4] Lovén appears to have been so far influenced by my criticisms on his comparison of the radially placed under-basals of *Marsupites* with the interradial genitals of *Salenia* that he makes no further reference to the former type, although in his earlier "Études" he laid great stress upon its resemblance to *Salenia*. This is unfortunate, because the presence of a dorsocentral in *Marsupites*, as well as of under-basals homologous with those of *Cyathocrinus*, proves conclusively that the latter cannot represent the dorsocentral of *Marsupites*, and therefore of *Salenia*, as Lovén formerly supposed.

[5] *Quart. Journ. Micr. Sci.*, 1884, vol. xxiv., N. S., p. 11.

[6] *Ibid.*, pp. 29–34.

above. Further, these plates "are large and well-developed in the adult forms in *Pentagonaster semilunatus, Gymnasteria carinifera,* in various species of *Pentaceros,* and a large number of the Goniasteridæ."

It thus appears that a small number of Ophiurids and a larger number of Starfishes have two rings of plates between the radials and the dorsocentral, just as is the case in *Marsupites;* though in the majority of the members of both groups there is only one ring, the elements of which are interradial, as is the case in all the Urchins, so far as is yet known. The homology of these interradial plates with the basals of the Pentacrinoid larva and of *Marsupites* is a part of Lovén's theory; while he long ago pointed out the homology between the central abactinal plate of the Starfish larva and the dorsocentral of *Marsupites.*[1] I do not see therefore, how he can do otherwise than accept the views of Sladen and myself respecting the homology of the radial plates immediately surrounding the dorsocentral of *Ophiomusium, Amphiura, Asterias,* and *Zoroaster* with the under-basals of *Marsupites.* In both cases these radial plates separate the dorsocentral from an interradial series which are called basals in a Crinoid and genitals in an Urchin or Starfish, *i.e.,* the plates for which Lovén proposes the general name of "costals." I do not imagine that he will deny (1) that the radial plates between the costals and dorsocentral of *Marsupites* are homologous with the radial plates between the costals and dorsocentral of the young *Asterias;* nor (2) that these radial plates are homologous with the under-basals of *Cyathocrinus,* which are immediately within the basals, or as he prefers to call them, costals. But, according to his present view, these under-basals of *Cyathocrinus* represent the dorsocentral of the young *Asterias.* There is, however, no reason to seek for the homologue of the five under-basals of a dicyclic Crinoid in the single dorsocentral of a larval Starfish; for this dorsocentral is surrounded by five plates which correspond exactly in their relative positions with the under-basals of *Marsupites,* and therefore of other dicyclic Crinoids, including *Cyathocrinus.*

If I may be permitted to use here an expression employed by Prof. Lovén with respect to another homology which he establishes, I would say that "to anyone believing in the consistency of Nature's ways, there is no reason whatever for doubting" that the apical systems of some Asterids and Ophiurids contain plates which are truly homologous with the under-basals of a Crinoid. It is unfortunate that their presence was not discovered in time to be noticed by Prof. Lovén in his recent discussion of the question; for I am sanguine enough to believe that it would have led him to reconsider his views respecting the homology of the five under-basals of a Crinoid with the primitively single dorsocentral of a Starfish.

The interradial plates in the apical system of a Starfish or Urchin are usually known as the genitals; but this term, "besides being expressive of incidental relations peculiar

[1] Études, *loc. cit.*, pp. 72, 86.

to the Echinoidea and partly to the Asteriadea, cannot by any means be applied to the homologous parts in the Crinoid," *i.e.*, to the basal plates. Lovén,[1] however, objects to the extension of the latter name to the so called genitals of Urchins and Starfishes, because the position of their apical plates, "while basal in the Crinoidea, is culminating in the Echinoidea and the Asteriadea, and consequently any appellation involving the notion of a basal position must be avoided."[2] There is undoubtedly some force in this objection; and I have long been endeavouring to find some general expression that would conveniently describe the interradial plates in the apical system of all Echinoderms. Not having succeeded in this quest, I have been obliged to fall back upon the word "basals." The interradial position of these plates in the calyx of a Crinoid, as defined by Müller,[3] is now universally recognised, and the use of the word is not likely therefore to lead to any confusion respecting the position of the plates with regard to the general symmetry of the Echinoderm type; while it has the further advantage of avoiding the multiplication of "terms already too numerous." As Lovén objects to the use of "basals" for the reasons given above, he seeks to avoid the introduction of new names by reviving the old term "costals" of Miller. To this there could be no possible objection were it only employed in the sense in which it was generally used by Miller, but this is unfortunately not the case. In seven out of the nine genera which were described by Miller as having costal plates, this term was used for the radial plates of the calyx; while it was only in describing some species (not all) of *Cyathocrinus* that he employed the term costals, for the interradial plates of the calyx or basals, and in the case of *Marsupites* he gave this name to the under-basals. Lovén admits this inconsistency,[4] but adds that "it has always been considered allowable to suggest the use in a strict sense of a term elsewhere vaguely applied." This is of course quite true, but the term should surely be limited to that sense in which it was most generally used by its author. This is not the case, however, with Lovén's revival of the term "costals," for he employs it to designate the basal plates which were only called costals by Miller in four out of the many species described by him; while he applied this name to the radials in all the other cases in which he used it at all, except in that of *Marsupites*. I cannot help feeling, therefore, that this revival of a name which has been disused for half a century is somewhat inexpedient, and is likely to lead to a confusion between the radial and interradial plates of the apical system which it is very desirable to avoid. Every one knows that the interradial abactinal plates of an Urchin or Starfish are not situated at the base of its body as they are in a Crinoid; and this reservation being made I do not see that there can be any objection to calling them basal plates. This would avoid all possibility of any confusion with respect to their position as regards the general symmetry of the

[1] On Pourtalesia, *loc. cit.*, p. 63.

[2] It may be noted with respect to this point that when Lovén inverts an Urchin for a better comparison of its calyx with that of a Crinoid, his "costal" plates (the genitals) really do become "basal" in position (see p. 414).

[3] Bau des Pentacrinus, *loc. cit.*, p. 25.

[4] On Pourtalesia, *loc. cit.*, pp. 63, 64.

Echinoderm, which seems to be inseparable from Lovén's use of the term. Should Prof. Lovén ever write anything more upon the apical system of Echinoderms, he cannot avoid referring to the radial plates between the dorsocentral and the so called genitals (costals or basals) of an Asterid. He cannot speak of them by the name which was given them by Sladen who discovered them, viz., "under-basals," for this term would be meaningless and confusing unless the plates outside them (the costals of Lovén) were also called basals; and he would therefore have to invent a new name for them, a proceeding to which he objects, or else adopt the terminology of Sladen and myself. I am sanguine enough to hope, not only that this will be the case, but also that the presence in Asterids and Ophiurids of plates homologous with the under-basals of Crinoids will lead him to abandon his theory of the homology of these under-basals with the dorsocentral of an Urchin or Starfish. I little expected six years ago to get so complete a confirmation of the views I then expressed as the presence of a "dicyclic base" in several Asterids and Ophiurids as well as in *Cyathocrinus* and *Marsupites*. The similarity in structure of the apical system in all the groups of brachiate Echinoderms thus becomes exceedingly striking; and it affords a further proof (if such were needed) of the homology between the apical systems of the Echinozoa and the Pelmatozoa respectively.

Two authors, however, have been led to an entirely different conclusion respecting the interradial abactinal plates of the Starfish larva from that of Lovén, Agassiz, Sladen, and myself. Ludwig regards them as homologous with the orals of a Crinoid, because one of the latter is pierced by the primitive water-tube;[1] while the madreporite of an adult Starfish is in relation with one of the so called genital plates (costals or basals). The morphological difficulties inseparable from this inversion of the relations between a Starfish and a Crinoid, as ordinarily conceived, have been discussed by Sladen[2] and myself.[3] With the exception of Studer,[4] whose errors have been discussed elsewhere,[5] no other writer has alluded to the subject; though it has recently made its appearance in a somewhat modified form. Perrier stated two years ago[6] that the primary interradial plates around the dorsocentral of the young *Brisinga* develop into the so called odontophores of the adult. The former are the plates which are usually known as the genitals (costals of Lovén; basals of Sladen and myself); and if Perrier's statement be correct, the views of Lovén, Agassiz, Sladen, and myself respecting the homology of the apical plates through the whole group of Echinoderms are no longer tenable. No proofs of it have yet been offered, however, though in a later note by Perrier[7] the following passage appears, "Les jeunes Astéries, les jeunes *Brisinga* présentent aussi, comme Lovén et nous-même

[1] *Zeitschr. f. wiss. Zool.*, Bd. xxxiv. p. 318, 1880.

[2] *Quart. Journ. Micr. Sci.*, 1884, vol. xxiv., N. S., pp. 35–40.

[3] *Ibid.*, 1880, vol. xx., N. S., pp. 322–329.

[4] Uebersicht über die Ophiuriden welche während der Reise S.M.S. "Gazelle" um die Erde, 1874–76, gesammelt wurden, *Abhandl. d. k. Akad. d. Wiss. Berlin*, aus dem Jahre 1882, Phys. Kl. Abh., i. p. 10.

[5] *Quart. Journ. Micr. Sci.*, 1884, vol. xxiv., N. S., pp. 15–18.

[6] Note sur les Brisinga, *Comptes rendus*, t. xcv., 1882, p. 63.

[7] *Ibid.*, p. 1381.

l'avons établi, des plaques dorsales disposées au début, comme celles du calice des Crinoïdes ; *nous avons démontré* que, chez les *Brisinga*, les plaques de la première rangée deviennent les odontophores." Even yet, however, no figures of the various developmental stages of *Brisinga* have been published in "demonstration" of Perrier's statements, which were summarised as follows, "Ainsi les odontophores sont les restes des pièces du premier rang du disque primitif de la *Brisinga*. L'identité évidente du plan d'organisation des *Brisinga* et des Astéries proprement dites rend la même conclusion probable pour les autres Étoiles de mer." It is undoubtedly probable that what is true of *Brisinga* also applies to all the other Asterids; and it is therefore the more desirable that some proof should be offered of the very definite statements made by Perrier. They have recently been disputed by Sladen[1] on the ground that in all the Starfishes of which the embryonic stages are sufficiently known, the basals and odontophores are "separate and distinct, and co-exist independently from their first formation;" while he further expresses his belief, based on sound morphological arguments, that the origin assigned by Perrier to the odontophores of an Asterid is theoretically impossible.

Perrier has recently repeated his statements in somewhat greater detail,[2] and having compared Lovén's figures of the young *Asterias glacialis* with his young specimens of *Brisinga*, he says that he has no doubt whatever, "que les choses se passent de la même façon dans les deux genres, et nous pouvons, dès lors, affirmer que les pièces radiales (*sic*) des très jeunes Asteriadæ deviennent dans cette ordre de Stellérides les odontophores."

Unfortunately for his theory, however, these *interradial* abactinal plates of the young *Asterias* develop in other Starfishes into relatively large plates which remain in more or less close relation with the dorsocentral, and are the very plates described as basals by Sladen not only in the larval *Asterias*, but also in the following genera—*Zoroaster*,[3] *Pentagonaster*, *Tosia*, *Astrogonium*, *Stellaster*, *Nectria*, *Ferdina*, *Pentaceros*, *Gymnasteria*, and others.

As there is an odontophore on the ventral side in each of these types, it is perfectly

[1] *Quart. Journ. Micr. Sci.*, 1884, vol. xxiv., N. S., p. 39.

[2] Mémoire sur les Étoiles de Mer recueillies dans la mer des Antilles et le Golfe du Mexique durant les expéditions de dragage faites sous la direction de M. Alexandre Agassiz, *Nouv. Archiv. du Mus. d'Hist. Nat.*, 2me sér., 1884, t. vi. p. 159.

[3] Several months before the appearance of Perrier's Report upon the West Indian Starfishes, Sladen figured the apical system of *Zoroaster fulgens*, and described it in the following terms: "Surrounding a dorsocentral and five small radially placed plates are five large plates interradial in position; and outside and alternating with these are five similar but rather smaller radially placed plates. . . . It will be noted that these plates represent in a remarkable manner the dorsocentral, the under-basals, the basals, and the radials respectively of the Crinoid calyx" (Asteroidea dredged in the Faröe Channel during the cruise of H.M.S. "Triton" in August 1882, *Trans. Roy. Soc. Edin.*, vol. xxxii. p. 160, figs. 9, 11). Precisely the same arrangement appears in the apical system of *Zoroaster ackleyi*, so far as one can judge from Perrier's figure of an entire specimen (*Nouv. Archiv. du Mus. d'Hist. Nat.*, 2me sér., 1884, t. vi. pl. iii. fig. 1); but he makes no mention of *Zoroaster fulgens*. Even if he had not seen Sladen's reference to it, one would have thought that he would have been struck by the Crinoidal aspect of *Zoroaster ackleyi*, though he does not refer to it at all, and he gives no detailed description of the plates. It would be interesting to know his reasons for believing that the large interradial plates in the immediate neighbourhood of the dorsocentral are not the "plaques de la première rangée" of the larva, which occupy exactly the same position with reference to the dorsocentral, and are believed by Perrier to become the odontophores in all Starfishes *except Caulaster*.

clear that this structure cannot have been developed from the primary interradial plates in the abactinal system of the larva; for these last remain in the apical system, just as they do in the Urchins. Sladen's observations, to say nothing of those of Lovén, render Perrier's views respecting the development of the odontophores of an *Asterias* from the primary interradial plates round the dorsocentral of the larva, absolutely untenable, and one is therefore the less disposed to accept his statements concerning *Brisinga*, of which no proof has yet been offered to his fellow-workers.

In connection with this subject he has recently advanced some theories respecting the mutual relations of a Crinoid and an Urchin which are altogether at variance with those of most other naturalists, except perhaps Ludwig. He thinks that in comparing the apical system of an Urchin with the calyx of a Crinoid, Lovén "a attribué à l'Oursin une position exactement inverse de sa position normale."[1] He regards an Urchin as a Crinoid with a large visceral mass to which the arms are fixed, as for example in *Eucalyptocrinus*;[2] while "la bouche serait située au point d'insertion du disque sur la tige." Under these circumstances the nervous system and ambulacral canals of an Urchin would have "exactement les mêmes rapports que ceux qui nous sont offerts par la Comatule. Il est à remarquer que précisément, en ce point, le calice de nombreux Crinoïdes pédonculés s'invagine, et présente des plaques qui ne sont pas sans analogie avec celles qui constituent la *lanterne d'Aristote* des Oursins et plus particulièrement des Clypéastres." This idea has since been further developed.[3] The arms of a Crinoid grow at their free end, while the new ambulacral plates of an Urchin are formed round the periproct. The base of the ambulacra is thus in the peristome. "Mais alors les pièces homologues des plaques calicinales des Crinoïdes sont non pas les dix plaques du périprocte, mais bien les pièces constitutives de la lanterne d'Aristote. Quelque hardie que paraisse cette interprétation . . . . . nous sommes persuadé que tout esprit non prévenu sera frappé de l'étroite ressemblance d'un Oursin régulier avec des Crinoïdes tels que le *Callicrinus* et surtout les *Eucalyptocrinus*." I fear that in this matter I cannot be said to have an "esprit non prévenu"; but it certainly appears to me somewhat rash to attempt to overthrow the generally accepted ideas respecting the mutual relations of an Urchin and a Crinoid by reference to such very highly specialised types as *Eucalyptocrinus* and *Callicrinus*. Both in this respect and in the comparison of the Crinoidal calyx to the lantern of Aristotle, I cannot help feeling that Prof. Perrier has altogether lost sight of the embryological arguments by which questions of homology are generally decided. The calyx of a Crinoid and the apical system of an Urchin or Starfish have precisely the same relations to the vaso-peritoneal apparatus of the larval Echinoderm; and until some better reason can be adduced for disregarding this relation than a more or less uncertain resemblance between

[1] *Nouv. Archiv. du Mus. d'Hist. Nat.*, 2me sér., 1884, t. vi. p. 161.
[2] *Comptes rendus*, t. xcviii. p. 1450.
[3] *Nouv. Archiv. du Mus. d'Hist. Nat.*, 2me sér., 1884, t. vi. p. 161.

a stemless Urchin and a highly specialised Palæocrinoid, I think that most naturalists will be inclined to regard the mouth of an Urchin as representing that of a Crinoid, and not the point of attachment between the stem and the body.

If this last view be correct, it follows, as Perrier points out, that "le dos des Astéries correspondrait à la region buccale des Oursins et non à leur region anale," which not even Ludwig would assert. Two years ago Perrier described a small Starfish which had been dredged by the "Travailleur," and was distinguished by the possession of a small dorsal appendage comparable to the stem of a Crinoid.[1] He stated that "quelques caractères des Astéries dont nous avons à parler ici paraissent indiquer que l'appendice dorsal dont elles sont munies est bien réellement l'homologue du pédoncule des Crinoïdes." He named the type *Caulaster*, and added that it is allied to *Ctenodiscus*. "Il existe chez ces derniers un léger tubercule qui nous paraît homologue de l'appendice dorsal des *Caulaster*, et peut-être en pourrait-on rapprocher un bouton saillant qui, chez les *Astropecten*, occupe la place où se trouve l'anus chez les autres Étoiles de mer." Sladen subsequently pointed out that a central epiproctal prominence of this kind is very general in the family Astropectinidæ.[2] It is "frequently developed into an elongate tubular prolongation" in the subfamily Porcellanasteridæ. He doubted the affinity of *Caulaster* with *Ctenodiscus*, and was inclined to regard it as a young *Porcellanaster*. More recently Danielssen and Koren[3] have described a new genus *Ilyaster*, in which a disk of 30 mm. diameter bears an epiproctal process 8 mm. long and covered with paxillæ, as in the Astropectinidæ described by Sladen. They agree with Perrier in regarding it as homologous with the stem of a Crinoid; and it would appear that Agassiz is of the same opinion.[4] It may be that this view of the case is the right one; but it could only be satisfactorily proved to be so by the demonstration that the cavity of the epiproctal prolongation is derived from the right vaso-peritoneal tube. For it is a diverticulum of this division of the primitive body-cavity of *Comatula* which extends backwards and has the joints of the larval stem developed in its walls. Future observations upon the early larval stages of the Astropectinidæ would throw much light upon this question. Perrier's *Caulaster* appears to be the youngest known form possessing this curious appendage, and some of the plates of the primitive calycular system are still visible. "À la base de l'appendice dorsal, se trouvent en effet quatre grandes plaques calcaires, disposées en croix et portant chacune un petit piquant; ces plaques sont à peu pres orientées *dans la direction des bras;* une cinquième plaque, alterne avec deux d'entre elles et opposée à la plaque madréporique, fait évidemment partie du même cycle; cinq autres plaques plus petites viennent se placer dans les angles laissés libres par les cinq plaques de la première rangée. On ne peut manquer d'être frappé

[1] *Comptes rendus*, t. xcv. p. 1379.

[2] *Journ. Linn. Soc. Lond.* (Zool.), vol. xvii. p. 214.

[3] Den Norske Nordhavs-Expedition, xi.; Zoologie. Asteroidea, p. 101, pl. vii. fig. 16, 1884.

[4] Reports on the Results of Dredging by the U.S. Coast Survey steamer "Blake"; Report on the Echini, *Mem. Mus. Comp. Zoöl.*, vol. x., 1883, No. 7, p. 17.

de la ressemblance absolue de ces dix plaques alternes avec celles qui forment le périprocte des Oursins et que Lovén a rapprochées, à leur tour, de celles qui constituent le calice des Crinoïdes, opinion que nous aurons prochainement occasion de discuter. L'identité de disposition des plaques dorsales des *Caulaster* avec celles du calice de Crinoïdes est évidente."

It would appear, however, from the foregoing description that Perrier's comparison of the plates round the dorsal appendage of *Caulaster* with those forming the periproct of an Urchin cannot be followed out in detail. The first row of plates in *Caulaster*, if *radially* situated as Perrier states, cannot correspond to the first or inner row of the apical system of an Urchin; for these last are the genitals, and are situated *interradially*. Their homologues are the plates in the second row of *Caulaster*, which alternate with those of the first; while the second ring of plates in the Urchins, the oculars or true radials, appear not to be represented in *Caulaster*. If Perrier's description of the positions of the plates in this type be correct, its apical system consists, not of genitals and oculars (basals and radials) as in an Urchin, but of under-basals and basals; and the true radials must be so small as to have escaped his notice.

NOTE B.

(Page 36.)

On the Basals of Fossil Comatulæ.

In certain fossil Comatulæ the ends of the basals are visible on the exterior of the calyx between the radials and the centro-dorsal. They are sometimes quite small, as in some forms of *Pentacrinus decorus* (Pl. XXXIV. fig. 1; Pl. XXXV. figs. 1, 2; Pl. XXXVI. fig. 3); while in other species, such as *Solanocrinus scrobiculatus*, Münster, they may reach a considerable size. As long as basals were supposed to be absent in the calyx of the recent Comatulæ, their presence in fossil forms appeared to be a character of generic value. But after the discovery by Dr. Carpenter and Sir Wyville Thomson that the Pentacrinoid larva has true basal plates which eventually become metamorphosed into the concealed rosette, this distinction between the recent and fossil Comatulæ no longer holds good. Schlüter[1] recognised this fact in 1878, and pointed out that *Solanocrinus* was merely a synonym of de Freminville's name *Antedon*. He referred to this genus both *Solanocrinus costatus*, Goldfuss, and *Solanocrinus scrobiculatus*, Münster, together with two other fossil species, in both of which the basals appear on the exterior of the calyx. Zittel,[2] however, regarded *Solanocrinus* as a subgenus of *Antedon*, distinguished from it by the presence of external basals.

In the following year[3] the examination of a considerable number of fossil Comatulæ

[1] *Zeitschr. d. deutsch. geol. Gesellsch.*, Jahrg. 1878, pp. 36, 40.

[2] Palæontologie, vol. i. p. 396.

[3] On some undescribed Comatulæ from the British Secondary Rocks, *Quart. Journ. Geol. Soc.*, vol. xxxvi. pp. 36–46, 1880.

led me to adopt Schlüter's view, as de Loriol[1] had previously done. For I not unfrequently met with calyces in which basals might appear externally at some of the angles, but not at others; while in other fossil types no basals were visible at all. In both cases, however, the basals were present as more or less prismatic rods extending outwards from the centre of the under surface of the radial pentagon somewhat as in the *Pentacrinus decorus* represented in Pl. XXXIV. fig. 8. But they were not always long enough to reach the edge of the radial pentagon and appear externally between it and the centrodorsal; so that one side of a calyx would be that of an *Antedon* and the other that of a *Solanocrinus*. Under these circumstances it would seem that Schlüter was undoubtedly right in uniting *Solanocrinus* with *Antedon*. But in a Manual of Palæontology recently published by Hoernes,[2] Zittel's classification is still adopted, and *Solanocrinus* is placed as a subgenus of *Antedon*, differing from it in the presence of basals on the exterior of the calyx; while it is also described as represented by a living species and not by fossil ones only. This apparently refers to the doubtful genus *Comaster*, Agassiz, which is only known from the description given of it by Goldfuss.[3] Whatever be the nature of *Comaster*, however, the supposed difference between *Solanocrinus* and *Antedon* cannot any longer be regarded as of generic value.

NOTE C.

(Page 68.)

On the Excentric Position of the Mouth in *Actinometra*.

The genus *Actinometra* comprises quite two-fifths, if not more, of all the species of living Crinoids. The character by which it is most readily distinguished at first sight is the excentric position of the mouth, as was pointed out in 1877[4] and again in 1879;[5] while its generic position is recognised by Claus in the last edition of his Grundzüge der Zoologie with the character "Mund excentrisch" (Pl. LV. figs. 1, 2; Pl. LVI. figs. 7, 8; Pl. LXI. fig. 2; see also fig. 3 on p. 92).

In spite of these facts, however, Hoernes stated in his Palæontology (p. 131) that in recent Crinoids the mouth is always (*stets*) in the centre of the disk, which is very far from being the case, as explained above. This error was avoided by Zittel, whom Hoernes usually follows very closely; though the generic position of *Actinometra* was not fully recognised by the former author, who placed it along with *Solanocrinus* and *Promachocrinus* as a subgenus of *Antedon*. But all subsequent writers, Hoernes excepted, have recognised that *Antedon* and *Actinometra* are totally distinct generic types.

[1] Swiss Crinoids, p. 254.
[2] Elemente der Palæontologie, p. 149.
[3] Petrefacta Germaniæ, vol. i. p. 202; see also *Journ. Linn. Soc. Lond.* (Zool.), vol. xiii. p. 454, 1877.
[4] *Journ. Linn. Soc. Lond.* (Zool.), vol. xiii. p. 441, 1877.
[5] The Genus Actinometra, *Trans. Linn. Soc. Lond.* (Zool.), ser. 2, vol. ii. p. 18.

NOTE D.

(Pages 100, 106.)

On the Supposed Communication of the Chambered Organ and Labial Plexus with the Exterior.

Perrier's statements respecting the direct continuity of the water-tubes depending from the oral ring of the larva with the inner ends of the water-pores of the disk have recently been extended to the adult *Antedon*. He further asserts not only that some of the water-pores open into the more or less glandular tubules of the labial plexus, but also that the canals forming the inner ends of the water-pores on the lower part of the disk open into the cavities of the chambered organ.[1]

I will not go so far as to deny the truth of these statements; but can only say that the results which Prof. Perrier believes himself to have obtained by "l'étude minutieuse de plus de deux cents coupes" are far from being in accordance with those of Ludwig, Greeff, Teuscher, or myself. It seems to me unlikely that the complex relations of the canals forming the inner ends of the water-pores which Perrier describes should have entirely escaped the notice of all of us. I freely admit that I may have overlooked the connection of the water-pores with the water-tubes and with the labial plexus; for the state of preservation of my material has not been such as to yield sections of one-fortieth of a millimeter thick. But, on the other hand, I have carefully studied many more than two hundred sections, nearer two thousand in fact, of several different types; and I believe it to be impossible that I could have avoided seeing such a connection between the water-pores and the chambered organ as is described in the following sentence, "leur plexus se continue jusqu'à l'organe cloisonné dans les chambres duquel s'ouvrent encore chez l'*Antedon rosaceus* les canaux issus des entonnoirs inférieurs du disque."

The chambered organ of a *Comatula* is lodged within the cavity of the centro-dorsal basin, covered up by the rosette, and surrounded by the ring of united first radials (Pl. LXI. fig. 2). It is therefore a perfect mystery to me how any of these canals which lead inwards from the ciliated water-pores and traverse the perisome of the disk can possibly open into its chambers.

Perrier describes himself as having been the first since the time of Müller to draw attention to these ciliated water-pores;[2] and he gives the date of his having done so as 1872.[3] In making this claim, however, he entirely ignores the fact that on the 21st of March 1871 Grimm had communicated a description of them with illustrative figures to the St. Petersburg Academy.[4] His description and figures were published in 1872, and

[1] Anatomie des Échinodermes; sur l'organisation des Comatules adultes, *Comptes rendus*, t. xcviii., No. 23, 1884, p. 1449.

[2] *Comptes rendus*, t. xcviii. p. 1449.

[3] Recherches sur l'anatomie et la régénération des bras de la Comatula rosacea, *Archives d. Zool. expér.*, vol. ii. p. 42.

[4] Zum feineren Bau der Crinoiden, *Bull. Acad. Sci. St. Petersb.*, t. xvii., 1872, col. 3–9, Mit einer Tafel.

Perrier cannot well be unaware of the fact at the present time, as it is noticed in the text of Ludwig's work on the Crinoids, and the paper is properly quoted in his bibliography. It is difficult, therefore, to see on what grounds Perrier bases his claim respecting the rediscovery of these ciliated funnels, "sur lesquels, depuis Johannes Müller, j'ai le premier attiré l'attention (1872)." When he published the paper here referred to, he had only made a superficial examination of these openings, each of which he described as leading into a small cul-de-sac. It would seem indeed as if he were then unaware, not only of Grimm's more correct observations of the previous year, which may be readily understood, but also of Müller's description of these pores *published nearly thirty years before*;[1] for he never mentioned Müller at all, and suggested that the pores might be special sense organs! Now, however, he tells us that they have a threefold connection—(1) with the water-vascular ring; (2) with the plexus of glandular tubules round the gullet; (3) with the cavities of the chambered organ. No other observers have noticed these points, and Prof. Perrier's proofs of his statements will be awaited with much interest.

NOTE E.

(Page 102.)

On the Intervisceral Blood-Vessels.

Perrier admits in his latest note[2] that diverticula of the cavity of the axial organ extend through the coelom, and that while some of them "apparaissent sur les coupes comme terminés en culs-de-sac, d'autres se plongent manifestement en canaux. Quelques-uns de ces canaux courent parmi les trabécules innombrables de la cavité générale; il en est qui se rendent vers les bras."

Some of these canals, which are regarded by Ludwig and myself as the intervisceral blood-vessels, are represented in Pl. LVII. figs. 2–5 and Pl. LX. figs. 3, 5—*ib.* If they are merely parts of a "vaste système aquifère," as Perrier believes, it is difficult to understand their existence; for the body-cavity through which they ramify already contains water which has entered it by the water-pores of the disk. What then is the object of a special set of aquiferous tubes distributed over the coils of the digestive canal and not communicating with the ambulacral system, but with the axial organ and the labial plexus; and why is it that their lumen is so frequently filled up with coagulum?

NOTE F.

(Page 106.)

On the Relation of the Vascular Systems of a Crinoid to those of the other Echinoderms.

Perrier's latest views respecting the vascular system of a Crinoid are expressed in the

[1] Durch diese capillaren Poren kann das Wasser bis in die Nähe des im Kelch liegenden Eingeweidesacks eindringen (Bau des Pentacrinus, *loc. cit.*, p. 49; see also the Bau der Echinodermen, *loc. cit.*, p. 63).

[2] *Comptes rendus*, t. xcviii. p. 1449.

following passage:[1]—"Ainsi le plus grande nombre des *entonnoirs ciliés*, *l'organe spongieux*, *l'organe axial*, les chambres de *l'organe cloisonné*, ne forment qu'un seul et même système, à la fois l'analogue et l'homologue du système formé chez les Oursins, les Astéries et les Ophiures par la *plaque madréporique*, le *canal hydrophore* ou *canal du sable* et la *glande ovoïde* qui lui est constamment annexée."

The above statement harmonises admirably with the theory which Perrier has so long been advocating respecting the fundamental unity of what are generally known as the water-vascular and the blood-vascular systems of Echinoderms. This theory is by no means new, and appeared to receive confirmation from the results of Perrier's study of the circulatory apparatus of the Urchins.[2] But Koehler's later observations on the same subject[3] have shown that several important points in the anatomy of the vascular system of an Urchin entirely escaped Perrier's notice. Although he adopts Perrier's views, his observations are capable of an altogether different interpretation, as I have shown elsewhere;[4] while they afford a strong confirmation to Ludwig's description of the vascular system of the Asterids.[5] This was founded upon the most careful and elaborate observations which have yet been published; and although their correctness has been called in question by Messrs. Perrier and Poirier,[6] none of the French zoologists have published a single figure in proof of their assertion that what is generally called the blood-vascular system of a Starfish communicates with the exterior through the madreporite.

As regards both Starfishes and Urchins therefore, the latest and most detailed observations do not tend to support the views of the French school. With respect to the Crinoids, however, the results which Perrier describes himself as having obtained, fall in with his theory in a manner which leaves nothing to be desired for completeness. In the case of the Urchins, according to Koehler, Perrier saw too little; while his two hundred *Comatula*-sections have revealed more to him than has resulted from all the observations of Ludwig, Teuscher, Greeff, and myself; and we, not Perrier, have seen too little. His theory, however, breaks down completely unless he can prove to the satisfaction of his colleagues that the labial plexus and chambered organ of a Crinoid are in direct communication with the exterior through the water-pores of the disk.

Unless these points can be properly demonstrated, the doctrine that the water-vessels and intervisceral blood-vessels of a Crinoid are only parts of a "vaste système aquifère" will have to be abandoned; while it does not harmonise at all with the present state of our knowledge of the morphology of the Echinozoa, except in so far as this is based upon the observations of the French Zoologists.

[1] *Comptes rendus*, t. xcviii. p. 1449.
[2] Recherches sur l'Appareil circulatoire des Oursins, *Archives d. Zool. expér.*, vol. iv., 1875, pp. 605–643, pls. xxiii., xxiv.
[3] Recherches sur les Echinides des Cotes de Provence, *loc. cit.*, pp. 58–79.
[4] *Quart. Journ. Micr. Sci.*, 1883, vol. xxiii., N. S., pp. 597–609.
[5] Beiträge zur Anatomie der Asteriden, *Zeitschr. f. wiss. Zool.*, Bd. xxx. pp. 99–131.
[6] Sur l'Appareil circulatoire des Étoiles de Mer, *Comptes rendus*, 1882, t. xciv. pp. 658–660.

There is strong reason to believe that the "ovoid gland" of an Urchin or Starfish does not communicate with the exterior through the madreporite as described by Perrier, while there can now be no question respecting its direct connection with what has been generally described as the oral blood-vascular ring of these types. Koehler's observations[1] have demonstrated this connection in the Urchins, although it was categorically denied by Perrier.[2] It thus seems probable that although the "ovoid gland" can no longer be described as a heart or even as a plexus of interlacing vessels, yet that it is a glandular structure interpolated in the blood-vascular system, and possibly one of the factories of the well known respiratory pigment of the Echinoderms. The following remarks by Welldon[3] are noteworthy in connection with this subject:—"It is not too much to say that in every group of invertebrates in which the vascular system has been at all carefully investigated, glandular appendages to the vessels have been found, which can, from their anatomical relations, have no other function than that of elaborating some of the constituents of the blood. . . . . In Echinoderms, the abundance of glandular cells in the cardiac plexus is probably a principal cause of the whole organ being regarded by many observers as an excretory apparatus."

NOTE G.

(Page 119.)

The Nervous System of the Crinoidea.

Since the section on the nervous system was written (*ante*, pp. 111–127), the subject has been still further discussed by various morphologists, most of whom, I am glad to say, have adopted the views advanced therein, and have strengthened them very considerably. As in so many other cases, it appears that the doctrine of the nervous nature of the axial cords in the skeleton of a Crinoid is not of such recent growth as has been supposed. For the following passage from von Schlotheim[4] would seem to show that a nervous function was attributed to the contents of the central canal of the skeleton more than sixty years ago:—"Da die Encriniten aber sämmtlich mit einer durch alle Zweige laufenden Nervenröhre versehen sind, und das Thier wenn es gleich mit der Wurzel angewachsen zu sein scheint, doch mit allen seinen festen Theilen beweglich bleibt, so gehört er offenbar nicht zu der Corallenarten, und macht nur ein merkwürdiges Verbindungsglied zwischen der Classe der Crustaceen und der Zoophyten aus."

A general, and, on the whole, tolerably accurate account of the morphology of living Crinoids was published by Weinberg[5] in the course of last year (1883). It is principally

[1] *Op. cit.*, p. 65, pl. 3, fig. 13.

[2] *Archives de Zool. expér.*, vol. iv., 1875, p. 613.

[3] On the Head-Kidney of Bdellostoma, with a suggestion as to the origin of the Suprarenal Bodies, *Quart. Journ. Micr. Sci.*, vol. xxiv., 1884, N. S., pp. 180, 181.

[4] Die Petrefactenkunde, Gotha, 1820, p. 327.

[5] Die Morphologie der lebenden Crinoideen mit Beziehung auf die Form Antedon rosacea, Linck, *Der Naturhistoriker*, 5 Jahrg. Marz-Juni Heft, 1883, pp. 266-307.

a summary of the researches of his predecessors, though he states that he has himself made some observations on *Antedon rosacea* at the Zoological Station at Trieste. It was perhaps not to be expected that he should have done otherwise than propagate the orthodox German view respecting the nervous system. But the account which he gives of the position in 1883 of the doctrine that the axial cords are nerves, is an extremely inadequate one. He states (p. 283) that it has been proved to be incorrect by Greeff; while a few pages further on (p. 290) he says that attempts have been made to support it by the supposition (*Annahme*) that fine branches proceed from the axial cords to the muscles and arm-segments—"Ludwig und Greeff wiesen jedoch das Unzulängliche und Unrichtige der von Carpenter angeführten Argumente nach." He then refers to the experiments performed by Dr. Carpenter, and leaves the question for further investigation.

Now, in the first place, the only comment which Greeff has made upon the doctrine that the axial cords are nerves has been a simple denial of its truth, without any attempt to discuss the subject at all;[1] and yet this denial is referred to by Weinberg as a proof of the doctrine being incorrect!

Ludwig, on the other hand, admits that the experimental evidence seems to afford very considerable support to Dr. Carpenter's views;[2] but he declines to accept them on account of the morphological difficulties which they involve. He has been unable to find the muscular branches from the axial cords which have been described by Dr. Carpenter and myself, and more recently by Perrier, Marshall, and Jickeli. But this does not justify Weinberg in stating that Ludwig has proved the arguments advanced by Dr. Carpenter and myself to be insufficient and incorrect; nor that the existence of these branches is merely a supposition. The fact that they were overlooked, not only by Teuscher and Greeff, but also by Ludwig and Weinberg, even after I had specially called attention to them, is no proof of their non-existence. Two figures of arm-sections, showing these branches, together with a further discussion of the whole question, were published in my paper[3] On the Minute Anatomy of the Brachiate Echinoderms, which appeared two years before Weinberg wrote his résumé, but is not referred to by him at all.

Another point of considerable interest in its bearings on this question is left entirely unnoticed by Weinberg, though it was fully explained in a paper[4] which he quotes, and it was illustrated by a diagram which also shows the branches of the axial cords; although, according to Weinberg, the existence of these branches is a mere supposition. I refer to the frequent absence of the ambulacral nerve on more or fewer of the arms of *Actinometra*. Weinberg admits its absence on the oral pinnules of *Antedon*, for this was

[1] Ueber den Bau der Crinoideen, *Sitzungsb. d. Gesellsch. z. Beförd. d. gesammt. Naturwiss. zu Marburg*, Nro. 1, 1876, pp. 21, 22.

[2] Crinoideen, *loc. cit.*, p. 335.

[3] *Quart. Journ. Micr. Sci.*, 1881, vol. xxi., N. S., pp. 188–192.

[4] Remarks on the Anatomy of the Arms of the Crinoids, part ii., *Journ. Anat. and Phys.*, vol. xi., 1876, pp. 90–93.

discovered by Ludwig, whose observations he could not very well overlook. But he does not attempt to discuss the bearings of this fact on Ludwig's doctrine that the axial cords are the only nerves in the arm of a Crinoid. He likewise describes the regular alternating movements of the arms of a swimming *Comatula*, and the muscles by which these movements are effected; and he leaves it to be inferred that these muscles are under the control of the only nervous system of which he admits the existence, although experiments have clearly proved that this is not the case; while Ludwig has admitted that he could trace no branches proceeding to the muscles from the ambulacral nerve. As to this last point, however, Weinberg is altogether silent.

Until this present year no German morphologist, with the exception of Weinberg, had published any observations upon the Crinoids since the appearance of Ludwig's important work in 1877; and the authors of zoological text-books published in Germany have confined themselves with remarkable unanimity to reproducing Ludwig's assertions that the nervous system of a Crinoid is essentially similar to that of an Asterid, and is limited to the fibrillar bands beneath the ambulacra. Dr. Carpenter's views, if mentioned at all, which was rare, were regarded as untenable from their being altogether at variance with the established scheme of Echinoderm morphology. Claus, for example, describes the arrangement of the axial cords in the calyx in some detail, but says not a word about their functions; while their presence is not even mentioned by Gegenbaur. According to these writers, therefore, the nervous system of a complex and highly specialised type like *Pentacrinus* is exclusively represented by the subepithelial bands of the ambulacra and the oral ring which unites them beneath the peristome (Pl. LXII., *n*, *nr*). The extreme insignificance of these structures in comparison with the rest of the organism cannot fail to strike any one who examines the sections of the ambulacra represented on Pl. LVII.; and yet, according to the orthodox German morphology, they are the only nerves which a Crinoid possesses.

The theory that the axial cords are nerves has recently been restated by Dr. Carpenter,[1] with the additional support of a quantity of new facts which had been discovered since he last wrote on the subject, more than eight years ago. He concluded by saying, "those who refuse to accept them (my views) are bound, I think, either to disprove the facts, or to show that my deductions from them are unsound."

Within a very short time after the presentation of this communication to the Royal Society, two papers were published on the nervous system of the Crinoids, in which Dr. Carpenter's theory was unreservedly adopted and strengthened by a large body of additional evidence.

The second of these, by Professor A. Milnes Marshall,[2] will be best considered first. After a short historical sketch of the subject, he describes an elaborate series of experi-

[1] On the Nervous System of the Crinoidea, *Proc. Roy. Soc. Lond.*, vol. xxxvii., 1884, pp. 67–76.

[2] On the Nervous System of Antedon rosaceus, *Quart. Journ. Micr. Sci.*, vol. xxiv., N. S., 1884, pp. 507–548, pl. xxxv.

ments which have led him to the following conclusions:—"1. The central capsule and its prolongations, the axial cords and their branches, constitute the main nervous system of *Antedon*. 2. The central capsule is specially connected with the complex co-ordinated movements of swimming and of righting when inverted. 3. The axial cords act as both afferent and efferent nerves. 4. The subepithelial bands are probably also nerves, but their exact function, probably a special and subordinate one in connection with the ambulacral tentacles and epithelium, is not yet ascertained."

These conclusions are the result of a long series of experimental investigations, in which Dr. Carpenter's fundamental observations were repeated and largely extended.

Marshall's paper concludes with a valuable discussion of the morphological aspect of his results. Starting from the generally accepted doctrine that the Asterids are the most primitive group of the Echinoderms, he shows how this character is well illustrated by their nervous system. Hamann's observations have demonstrated that this "is in the form of a continuous nerve-sheath enclosing the whole body, and directly continuous with the external epidermis of which it forms the deepest layer. This nerve-sheath is thickened at certain places, notably along the ambulacral grooves, where it forms the five radial or ambulacral nerves." Marshall points out that the analogies of the Coelenterates, Chætognatha, and Palæonemertines all tend to show the primitive nature of the Asterid nervous system.[1] There is no difficulty about the relation of the nervous system of the remaining Echinozoa to that of the Asterids; but the case is different with the Crinoids, on account of the antambulacral position of their principal nerve centre and its radiating extensions. Marshall, however, is inclined to consider them as "descended from forms which agreed with the recent Asterids in possessing a complete nerve-sheath (though possibly very unlike Asterids in other respects);" and he is therefore "disposed to regard the antambulacral nervous system of a Crinoid, *i.e.*, the central capsule and axial cords with their branches, as being derived from the antambulacral part of the primitive nerve-sheath, and not as an entirely new set of structures possessed by no other Echinoderms."

He endeavours to show that the relations of the axial cords which lie in grooves on the surface of the radials of the Pentacrinoid larva (a permanent condition in some Palæocrinoids) are "very similar to those of the ambulacral nerves of an adult Ophiurid or Echinid, and as the latter have certainly acquired their adult condition by becoming detached from the epidermis and shifting inwards, so also may the same process be supposed to have occurred in the Crinoid." Too much weight must not be laid upon this point, however, for the supposed inward movement of the radial nerves of an Ophiurid or Echinid would be from the outer or ambulacral surface of the plate towards the inner one, *i.e.*, that next to the body-cavity.

On the other hand, in the developing Crinoidal calyx the axial cords are at first on the walls of the body-cavity, which are formed by the *inner* surfaces of the radials; but they

[1] Compare Chapter VI. pp. 113, 115.

gradually come to lie in canals within the radials, and so are relatively (though of course not absolutely) nearer the epidermis on the exterior of the body, which in this case is antambulacral.

The ontogenetic change in the relative position of the axial cords of a Crinoid is thus directly the opposite of that which Marshall supposes to have taken place phylogenetically. On his theory the antambulacral portion of the primitive nerve-sheath should commence by being outside the radials, between them and the epidermis; whereas, as he himself admits, the radials are at first in the form of "calcareous plates between the cords and the integument." His argument is, therefore, only one of analogy, and the outward movement of the axial cords in the Crinoid larva is not comparable morphologically to the inward movement, which must have taken place during the development of the radial nerve of an Urchin from the primitive nerve-sheath of a Starfish.

It appears to me, however, that there is a possible view of the phylogeny of the axial cords which would not conflict in this way with their ontogenetic movement. According to Götte's observations, the ciliated ambulacral epithelium of the Crinoids is derived from the cellular lining of the left peritoneal sac;[1] so that the ambulacral nerve, which is in such close relation with this epithelium, is endodermic in its origin. On the other hand, the axial cords of a larval Crinoid lie in the walls of the dorsal portion of the body-cavity, which is lined by an epithelium derived from that of the right peritoneal sac; and I would therefore suggest that the embryonic axial cords might have the same primitive relation to this epithelium as the ambulacral nerves must have to that of the left peritoneal sac, if Götte's observations be correct. The outward movement of the cords during development, away from the epithelium of the body-cavity, would then be, so to speak, serially homologous with the supposed inward movement of the ambulacral nerves of an Urchin. In other words, the axial cords are the nerves of the right antimer, while the subepithelial bands of the ambulacra are those of the left antimer, both being derived in the first instance from the epithelium of the enterocoel.

In the Neocrinoids the axial cords eventually come to be some little distance from this epithelium; though they must have remained close to it in those Palæocrinoids which had imperforate radials, just as they are in the Pentacrinoid larva. A variation of the same nature, though of course altogether different in degree, presents itself in the relation of the ambulacral nerve in certain species of Neocrinoids. I refer to the presence or absence of a delicate connective tissue lamella between the nerve and the overlying epithelium. This layer is often very conspicuous in *Antedon eschrichti*, but occasionally seems to be absent; while its presence in *Antedon rosacea* is doubtful. I have never satisfied myself of its existence in any other species, though Ludwig and Marshall seem to quote me as having noted its occurrence in *Actinometra*. Ludwig[2] long ago

[1] *Archiv. f. mikrosk. Anat.*, Bd. xii. pp. 591–593.

[2] Beiträge zur Anatomie der Crinoideen, *Nachricht. v. d. kgl. Gesellsch. d. Wiss. zu Göttingen*, No. 5, 1876, p. 108.

suggested that the great development and calcification of this lamella would bring the ambulacral nerve into a position corresponding to that of the radial nerve-cords of Ophiurids and Echinids. Marshall[1] has recently put forward a somewhat similar hypothesis, viz., that this lamella "probably represents the earliest stage in the process by which the nerve becomes detached from the epidermis and shifted inwards." We know far too little, however, about the ontogeny of the Echinoderm nervous system to do more than speculate on this subject. According to Selenka and Ludwig the nervous system of Asterids and Holothurids is of ectodermic origin; while Götte's observations lead to the conclusion that the ambulacral nerves of Crinoids are derived from the endoderm. Should this really be the case, there can be no difficulty in taking the same view respecting the axial cords.[2] But even then we get no clue to the morphology of the central capsule, as Marshall has conveniently called the fibrillar envelope of the chambered organ in which the axial cords originate.

He remarks[3] that "Dr Carpenter's observations lead to the belief that, at any rate in its present form, it is connected with the change from the pedunculate to the free-swimming condition; and it is worthy of notice that the two actions with which it has been found to be specially concerned physiologically, *i.e.*, the movements of swimming and of righting, are ones that the pedunculate form, from the very nature of things, can never exercise."

I cannot quite share Marshall's belief in the relation between the central capsule and the change from the attached to the free mode of life. The only difference between the chambered organ of a *Comatula* and that of a Stalked Crinoid is the absence of any cirrus-vessels in connection with the latter; for these come off from the peripheral vessels of the stem (Pl. XXIV. fig. 4; Pl. LXII.—*cv*), which are the downward extensions of the cavities of the chambered organ. But the central capsule or fibrillar envelope of these cavities, which in *Comatula* "is specially connected with the complex co-ordinated movements of swimming and of righting when inverted," is equally present in all the Stalked Crinoids (Pl. VIIb. fig. 2; Pl. XXIV. figs. 6, 7; Pl. LVIII. figs. 1, 3; Pl. LXII.); and there can be no doubt that it controls the movements of flexion and extension of the arms. The latter of these is essential to the proper nutrition of the animal; and I can quite believe that the arms may also be used for swimming by those Pentacrinidæ, such as *Pentacrinus maclearanus, Pentacrinus alternicirrus,* and *Pentacrinus wyville-thomsoni,* which have short stems terminating below at a nodal joint (Pl. XVI. fig. 1; Pl. XIX. fig. 1). In all the Stalked Crinoids the central capsule is continued downwards into the stem as a sheath around the central vascular axis (Pl. VIIa. figs. 1, 2; Pl. XXIV. figs. 1–6; Pl. LXII.—*ca*), and it gives off branches which spread out towards the surface of the stem,

[1] *Loc. cit.*, p. 546.

[2] Whatever be the origin of these cords, they are essentially mesodermic in their distribution; and it is in this sense that I have spoken of them in the text as constituting a mesodermic nervous system (p. 114).

[3] *Loc. cit.*, p. 547.

and probably form a subepidermic plexus (Pl. VIIa. fig. 1; Pl. XXIV. fig. 2—*ca'*). Extensions of it also proceed into the cirri round the cirrus-vessels (Pl. LXII., *ev*), and give off similar radiating branches. Jickeli's observations on *Antedon rosacea* show that the movements of the cirri, like those of the arms, are dependent upon an influence proceeding from their axial cords;[1] and it is clear that if the central capsule and axial cords of *Comatula* constitute its principal nervous system (as few will now deny), this must be regarded as also extending throughout the whole stem of a Stalked Crinoid, even though it reach 70 feet in length, as in the fossil *Extracrinus subangularis*.

It may also be assumed with tolerable certainty that there was a similar neuro-vascular axis in the stem of all the fossil Pelmatozoa, including the Blastoids. These had no arms attached to the radials, as a Crinoid has. But if they had the same arrangement of axial cords in the basals and radials as prevail in a Crinoid, which I see no reason to doubt, it is unlikely that the radial cords, starting from the circular commissure (fig. 20, *A*) should have ended in the forks of the radials which receive the distal ends of the ambulacra. In the Mesozoic *Phyllocrinus* the radials have almost exactly the same forked shape as those of a *Pentremites;* but the point where the limbs of each fork separate is marked by an articular facet to which the arm was attached.

In a Blastoid, however, the sinus between the two limbs of the radial is filled up by the ambulacrum, which terminates in a more or less prominent lip at the same point in the body of the radial as is occupied by the articular facet in *Phyllocrinus*. That the axial cord in the radial of a *Pentremites* (fig. 20, *A*) ended in this lip seems to me improbable; and I cannot help suspecting that it may here have become continuous with the nerve of the ambulacrum. From what we know of the ambulacral nerves of recent Crinoids, this is not likely *per se* to have been related to any other movements but those of the tentacles, even if these organs were present; while it may perhaps have been removed from the superficial epithelium, as in an Urchin, and lodged within one of the canals in the lancet plate. This would have brought it deep enough to be continuous with the axial cord of the radial at the termination of the ambulacrum. The movements of the so called pinnules of the Blastoid would thus have been controlled by the central capsule, instead of by the oral ring, which is not likely to have had anything to do with them; for the oral ring of a recent Crinoid has absolutely no control over the movements of any part of the calcareous skeleton; and the jointed pinnules of a Blastoid cannot have remained permanently closed over the ambulacra, as they are found in the fossils (fig. 20).

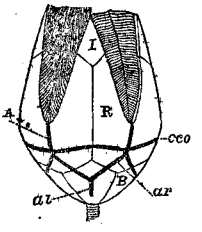


FIG. 20.—Diagram showing the arrangement of the axial cords in the calyx of a *Pentremites*, supposing it to be the same as in the calyx of a Crinoid. The pinnules are represented as preserved on one ambulacrum, but not on the other. *A*, axial cord of the ray; *ai*, primary interradial cord; *ar*, one of the converging radial cords which result from its bifurcation; *B*, basal; *cco*, circular commissure; *I*, interradial plate (deltoid of Roemer); *R*, radial.

[1] See the quotation from Agassiz, *ante*, p. 333.

Lovén has recently pointed out the singularly Crinoidal appearance of the calycinal system of a Triassic Urchin, *Tiarechinus princeps*, Laube.[1] "The relative magnitude of the entire system, the prominent share it takes among the constituents of the skeleton, the forms and proportions of its parts, are such as forcibly to recall the calyx of some Palæocrinoid, and to justify a desire to turn the Echinoid upside down and to see the calycinal system in its imaginary original position, when it formed a part of some remote ancestral type. In this respect the resemblance becomes still more striking."

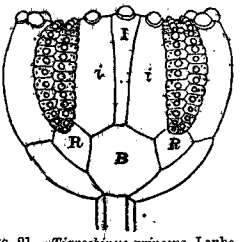


FIG. 21.—*Tiarechinus princeps*, Laube, inverted so as to show the resemblance of its apical system to the calyx of a Crinoid. (The figure, but not the letters, after Lovén.) *B*, basal; *I*, single, median interradial; *i*, lateral interradials; *R*, radial.

Let us compare Lovén's figure (fig. 21) with that of the Blastoid (fig. 20). Each has relatively large basals (*B*); but the radials of the Pentremite (*R*) are small in *Tiarechinus*, their limbs being replaced by the two lateral plates of the interradius (*i*) which enclose the ambulacrum. In *Tiarechinus*, just as in the Blastoid, however, the ambulacrum ends against the body of the corresponding radial; and its nerve, lying beneath the ambulacral plates as in recent Echini, would be in a position where it could be directly continuous with an axial cord situated within the radial or on its inner face, if only *Tiarechinus* were a Crinoid instead of an Urchin. I would not, of course, be understood as saying that *Tiarechinus* had a central capsule and axial cords proceeding from it. My only object has been to point out that Lovén's happy comparison of this curious type with an inverted Crinoid affects other systems of organs besides that of the calycular plates. At the same time, considering the number of Asterids which have a calyx of relatively large plates, and the fact that there is a continuous nerve sheath on the dorsal surface, I think it not improbable that indications of a central capsule and axial cords may eventually be discovered in the Echinozoa.

It remains now to notice the observations of Dr. Jickeli, which, though only published recently, are nearly four years old.[2] Like Marshall he has made an elaborate series of experiments in extension and confirmation of those originally described by Dr. Carpenter, whose views respecting the nervous nature of the central capsule and axial cords he adopts unreservedly. He further believes that the fibrillar bundles uniting the cirrus-joints and those forming the dorsal and interarticular ligaments (as they are described above) in the arms (Pl. LXII., *ld*, *li*) are muscular in function, though differing in many points from the fibres which have hitherto been exclusively described as muscles (Pl. LXII., *m*); for when the axial cord of a detached cirrus is stimulated "so krümmt sich derselbe auf das Heftigste zusammen und geräth selbst in Tetanus."[3]

[1] On Pourtalesia, *loc. cit.*, p. 65.

[2] Vorläufige Mittheilungen über den Bau der Echinodermen, 1, Ueber das Nervensystem und die Sinnesorgane der Comatula mediterranea, *Zool. Anzeiger*, vii. Jahrg., pp. 346-349 and 366-370, 1884.

[3] *Zool. Anzeiger*, vol. vii., 1884, p. 348.

This seems to indicate clearly that the interarticular fibres of the cirri are muscular in function, though not striated like the ventral fibres which unite the arm-joints, and have hitherto been regarded as the only true muscles of the Crinoid organisation.

Four years ago I pointed out that the appearance of some of my sections had led me to think that the axial cord of the arm consisted of two lateral fibrillar masses enclosing a central structure.[1] According to Jickeli[2] this last is a longitudinal septum between two tubes which contain blood-corpuscles; while the whole structure is enclosed in a sheath of nervous tissue. Within the calyx the tubes of the different rays unite laterally and "gehen durch eben solche das gekammerte Organ theilweise bedeckende Fortsätze in ein spongiöses Geflecht über, welches dem gekammerten Organ wie eine Käppe aufsitzt. Von diesem spongiösen Geflecht entspringen die Fortsetzungen in die Cirrhen. Die Wandung dieses Röhrensystems ist die nervöse Substanz, die Masse, welche dasselbe erfüllt, besteht aus geronnenem Plasma, in welches Blutzellen eingebacken sind." It does not appear, however, that these axial blood-tubes are in any way connected with the cavities of the chambered organ. Jickeli points out that his observations confirm the statements of Müller[3] respecting the presence of a blood-vessel within the central canal of the arms, which subsequent workers have generally considered to be erroneous. He finds that the elements of the nerve sheath surrounding these blood-vessels are most easily demonstrated in the radial axillaries where the axial cords of two arms unite, and he describes the presence of ganglionic cells with from two to six processes, some of which unite with those of other cells. He has also seen the muscular branches of the axial cords, the existence of which, according to Weinberg, is only a supposition; and by the use of polarised light he has traced these into the dorsal as well as into the ventral musculature.

He doubts the presence of a definite oral ring in the ambulacral nervous system. For he finds that the ventral nerves extend down into the fore-gut beneath its epithelium, which is directly continuous with that lining the food-grooves. The appearance of several of my sections, both of *Pentacrinus* and of *Comatula*, has led me to suspect this fact; but I have hesitated to say so, as I wished to verify it by making some sections of individuals which had been properly prepared for histological work. This having been done by Jickeli, I am glad to be able to confirm his observations.

He believes himself to have discovered yet another nervous structure in the Crinoid organisation, "es ist noch ein drittes bis dahin nicht bekanntes, im Bindegewebe gelagertes Nervencentrum vorhanden, welches die Mundöffnung umgibt, und die radialen Wassergefässe jederseits als ein gesonderter, an die Tentakeln in regelmässigen Abständen Zweige abgebender Strang begleitet."[4] The peripheral parts of this system appear to me to belong to what I have called the parambulacral network, situated in the ventral

[1] *Quart. Journ. Micr. Sci.*, 1881, vol. xxii., N. S., p. 187.
[2] *Zool. Anzeiger*, vol. vii. p. 368, 1884.
[3] Bau der Pentacrinus, *loc. cit.*, p. 22.
[4] *Zool. Anzeiger*, vol. vii. p. 370, 1884.

perisome of the arms and disk. Jickeli says, for example, "von diesem dritten Nervencentrum gehen auch starke Zweige in die ventrale Korperhaut und lösen sich dort in feine nervose Geflechte auf."[1] It will be strange indeed if these prove to be anything else than the ramifications of the ventral branches of the axial cords of the arms which I described long ago as extending to the edges of the food-groove (see fig. 4, p. 113; fig. 5, p. 121; and fig. 8, p. 123). I cannot say, however, that I have ever seen the pentagonal ring round the mouth which Jickeli mentions, nor even its radial extensions at the sides of the water-vessels; unless indeed these last be the lateral trunks which I have described above in *Actinometra nigra*, from sections now nearly nine years old (p. 122).

The branches of Jickeli's third nervous system which break up into a plexus in the ventral perisome appear to me to be identical with those which I described two years ago as extending along the sides of the ambulacra of *Antedon eschrichti* from the edge of the disk to the neighbourhood of the mouth.[2] A diagrammatic representation of them is given on p. 123, while illustrations of single sections, both of this species and of *Pentacrinus decorus*, are shown on Pl. LIX. figs. 2–7. These branches are unquestionably of the same nature as those occupying a similar position in the arms (Pl. LX. fig. 6, *a'*), and belong like them to the system of the central capsule and axial cords, with which last they are connected at the edge of the disk. But at the same time I fully believe that they are the peripheral portions of the third nervous system described by Jickeli. The so called papillæ of the tentacles have also attracted his attention, and he regards them as sense-organs of a somewhat complicated nature, supporting fine sensory hairs. He thus inclines to Perrier's view of the nature of these papillæ rather than to that of Ludwig, who regards them as glandular organs. Jickeli, however, describes them as being innervated by the branches of his third nerve-centre; while according to Perrier[3] they receive nerve-fibres from the ventral branches of the axial cords, which form what I have called the parambulacral network. But if I am right in identifying this with the peripheral part of Jickeli's third nervous system, his observations are completely in accordance with those of Perrier.

[1] *Zool. Anzeiger*, vol. vii. p. 369, 1884.
[2] *Quart. Journ. Micr. Sci.*, 1883, vol. xxiii., N. S., p. 615.
[3] *Comptes rendus*, t. xcvii. p. 188.

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The following list does not pretend to be a *complete* Bibliography of the Neocrinoidea, *i.e.*, to give a reference to every description of a fossil Crinoid which has appeared in the countless publications upon the Palæontology of the Secondary and Tertiary Periods. Neither is it meant to include every notice of a recent Crinoid in faunal and other lists. The numerous controversial references to fossil forms in epistolary communications to the Neues Jahrbuch by von Buch, von Meyer, and others are also mostly omitted, and must be sought for in the excellent Bibliography of de Koninck and le Hon.

But I have endeavoured to make the accompanying list complete for the two following classes of works:—(1) all those containing descriptions of new species of recent Crinoids; (2) all those which, though dealing principally with Palæocrinoids or with other Echinoderms, contain valuable information upon the Morphology of the Crinoids generally. The literature of the Pelmatozoa has increased at a very rapid rate since the publication of the admirable Bibliography by de Koninck and le Hon in 1854, which contained a chronological list of nearly all the earlier works on the subject.[1] We may hope ere long for a supplement to this as regards the Palæocrinoids from Messrs. Wachsmuth and Springer; and I trust in the course of time to be able to complete the following list by the addition of references to works on general palæontology which contain notices of Neocrinoids.

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The following short notices of recent Crinoids seem worth quoting *in extenso*. We have, unfortunately, no further knowledge of any of the types to which they relate.

I.

"Une espèce nouvelle d'Encrine vivante a été découverte par le révérend C. Pleydell à Newcastle sur la rivière Hunter, dans la Nouvelle Hollande; l'auteur propose de lui donner le nom d'*Encrinus australis*. Elle n'a pas de colonne vertebrale, mais le corps de l'animal a environ un cinquième de pouce de long, et est terminé dans cette direction par une base circulaire. À l'extrémité opposée du corps sont attachés cinq appendices claviculaires." *L'Institut*, 1845, p. 292.

Is this a Crinoid at all?

II.

"Professor Sigmund Schultze aus Greifswald zeigte einen neuen *Pentacrinus*, welcher ihm von Amboina übersandt ist, in Abbildungen vor und sprach über die drei Arten, welcher er in dieser seltenen, bisher nur in

sieben Exemplaren bekannten Thiergattung unterscheidet; der *Pentacrinus Guettardi*, der *Pentacrinus caput-Medusæ* und der *Pentacrinus Arndtii*." *Bericht ü. d. Versamml. deutsch. Naturf. in Karlsruhe*, 1858, p. 293.

Two new species, *Pentacrinus guettardi* and *Pentacrinus arndtii*, are mentioned here, but nothing is said as to which came from Amboina, nor as to the nature of the other. The Amboina specimen was probably a *Metacrinus*.

III.

"I learn from a correspondent at Melbourne, Mr. J. S. Poore, that during his visit to King George's Sound, Western Australia, he there dredged up from 8 fathoms a living Encrinite. The stem, which was attached to a stone, was about 6 inches long; the arms about 1½ inch, of a beautiful rose-colour or pink, fading to white." Sir. R. Owen in *Ann. and Mag. Nat. Hist.*, ser. 3, vol. ix., 1862, p. 486.

This may perhaps have been a Pentacrinoid larva, but if so, it was of most unusual size. Further information about it from Australian naturalists would be most valuable.

INDEX TO AUTHORS QUOTED.

Agassiz, A., 12, 18, 57, 130, 197, 204, 210, 306, 309, 331, 333, 390, 393, 398, 401, 413.
Agassiz, L., 64, 119, 197, 270–272.
Allman, G. J., 161, 164, 185.
Angelin, N. P., 41, 65, 66, 84, 172, 175, 176.
Apostolidès, N. C., 101.
d'Archiac, A., 245, 247, 323.
Austin, T., 39, 183, 187, 272, 274–278, 296, 301, 306, 388.
Baily, W. H., 284.
Baudélot, C., 117, 118.
Barrois, C., 154.
Bell, F. J., 303.
Beyrich, E., 37, 126, 223, 245, 275, 294.
Billings, E., 43, 75.
Blainville, H. M. D. de, 187, 272, 300, 303.
Bronn, H. G., 145, 188, 190, 191, 271, 294.
Buckland, W., 22, 39, 81, 272, 277, 300.
Buch, L. von, 190.
Burmeister, H., 186, 187, 191.
Carpenter, P. H., 2, 4, 18, 20, 25, 26, 35, 36, 39, 42, 46, 47, 49, 51, 52, 56, 57, 59, 60, 88, 94, 101, 102, 104–107, 143, 158, 165, 168, 169, 189, 213, 217, 227, 245, 250, 255, 259, 262, 268, 269, 273, 282, 284, 288, 293, 301, 306, 328, 331, 340, 343, 357, 370–372, 393–395, 398, 402, 403, 406, 408, 415, 416.
Carpenter, W. B., 1, 2, 8, 36, 40, 48, 50, 58, 59, 63, 67, 73, 87, 107, 108, 114, 116, 118, 132, 133, 245, 292, 402, 408, 409, 412.
Carpenter and Etheridge, 37, 49, 145, 147, 158.
Chapman, E. J., 151, 195, 196.
Charlesworth, E., 192.
Claus, C., 403, 409.
Cole, E., 18.
Danielssen and Koren, 8, 29, 71, 225–227, 231–234, 242, 401.
Desor, E., 272, 281.
Dixon, F., 34, 284.
Dujardin and Hupé, 191, 192, 197, 273, 301.
Ellis, J., 272, 274, 294, 300.
Emmons, S. F., 298.
Etheridge, R., 276, 296.
Etheridge, R., jun., 135.
Eudes-Deslongschamps, E., 20, 131, 213.
Filhol, H., 244, 269, 315–317, 319.
Forbes, E., 35, 144, 187, 190, 192, 245, 269, 272–274, 281.
Gegenbaur, C., 409.
Goette, A., 71, 157, 158, 167, 169, 411.
Goldfuss, G. A., 35, 158, 187, 272, 274, 284, 294, 302, 403.
Graff, L. von, 134, 135, 324, 347, 364.
Greeff, R., 120, 406, 408.
Grimm, O. von, 404.
Guéttard, J. E., 272, 274, 294, 300.
Hagenow, F. von, 323.
Hall, J., 19, 20, 53, 87, 193, 217.
Hall and Whitfield, 298.
Hamann, O., 112, 124, 410.
Hertwig, O., 115.
Hertwig, R., 114.
Hoek, P. P. C., 351.
Hoernes, R., 393, 394, 403.
Huxley, T. H., 75, 188, 192.
Jeffreys, J. G., 281, 313–315, 392.
Jickeli, C. F., 408, 413–416.
Koehler, R., 101, 105, 106, 112, 406, 407.
Koninck, L. G. de, 153, 223.
Lamarck, J., 272, 300.
Lankester, E. Ray, 186, 189.
Laube, G. C., 296, 414.
Leuckart, R., 186, 188, 190, 191, 193.
Linnaeus, C., 272, 300, 302.
Loriol, P. de, 9, 15, 17, 22, 25, 26, 35, 47, 126, 131, 135, 142, 146–148, 153, 183, 186, 188, 189, 201, 202, 212–216, 223, 225, 227, 245, 248, 256, 257, 270, 272–274, 276, 277, 281, 286, 297, 299, 403.
Lovén, S., 4, 67, 85, 368, 393–400, 402, 414.

Ludwig, H., 67, 86, 88, 89, 92–96, 101, 102, 104–106, 108, 111–113, 116–120, 124–127, 209, 210, 229, 230, 248, 250–254, 261, 268, 395, 398, 400, 404–406, 408, 409, 411, 412, 416.
Lütken, C. F., 4, 85, 145, 146, 168, 248, 273, 277, 283, 301–306, 308, 309, 311, 330, 333, 394.
Manzoni, A., 245.
Marshall, A. M., 255, 408–412.
Meek, F. B., 45, 53, 148, 184.
Meek and Hayden, 297, 298.
Meek and Worthen, 41, 61, 75, 87, 162, 163, 177, 217.
Meneghini, G., 238, 245–248, 258.
Meyer, A. B., 130.
Meyer, H. von, 34, 271, 272, 294.
Michelin, H., 216.
Miller, J. S., 73, 145, 151, 183, 189, 191, 272–275, 277, 278, 300, 302, 304, 306, 308, 397.
Miller, S. A., 20, 42–44, 183, 185, 192.
Milne-Edwards, A., 237, 269.
Moseley, H. N., 128, 129, 210, 320, 346, 348, 352, 354, 356, 359, 362, 365.
Müller, J., 2, 5, 8, 9, 49, 66, 73–77, 85, 86, 117, 145, 147, 170, 171, 179, 190, 191, 195, 196, 272, 274, 300, 302, 304, 306, 308, 394, 397, 404, 405, 415.
Müller, P. L. S., 300, 302.
Nicholson and Etheridge, 192.
Oersted, A. S., 301, 306, 307.
d'Orbigny, A., 9, 25, 54, 142, 183, 192, 197, 199, 245–249, 270, 272, 274, 370.
Parra, A., 301.
Perrier, E., 28–30, 47, 94, 101, 102, 104, 106–108, 117–119, 122, 127, 195, 244, 245, 262–266, 268, 269, 316, 398–402, 404–408, 416.
Perrier and Poirier, 406.
Phillips, J., 276.
Picard, K., 270, 294.
Pictet, F. J., 191, 192, 197, 273, 274.
Pourtalès, L. F. de, 65, 160, 197, 204, 245, 246, 248–250, 258, 259, 261–263, 265, 268, 306, 309, 330, 331.
Quenstedt, A., 4, 7, 15, 16, 20, 22, 24, 25, 34, 39, 54, 55, 142, 183, 187, 191, 211, 257, 273, 276–278, 281, 284, 286, 294, 296, 299, 308, 323.
Ramsay, A., 276.
Roemer, F., 48, 160, 186, 187, 190, 197, 211, 213.
Romanes and Ewart, 112, 115.
Salter, J. W., 192, 193.
Sars, M., 25, 28, 29, 72–74, 90, 107, 130, 245, 246, 248–254, 259, 261–265, 266, 268.
Schlotheim, E. F. von, 272, 273, 294, 300, 407.
Schlüter, C., 35, 144, 147, 148, 151, 212, 213, 371, 402, 403.
Schultze, L., 41, 47, 48, 152, 158, 160.
Selenka, E., 412.
Semper, C., 108, 110, 130, 133, 236.
Sigsbee, C. D., 332.
Simroth, H., 2, 116.
Sladen, W. P., 106, 168, 195, 303, 340, 368, 394 396, 398–401.
Steenstrup, J. J. S., 211.
Strombeck, A. von, 294.
Stüder, T., 398.
Suhm, R. von W., 133, 134, 369.
Teuscher, R., 118, 120, 404, 406.
Théel, H., 122.
Thomson, C. Wyville, 1, 4–6, 8, 12, 18, 19, 21, 22, 32, 37, 39, 48, 52, 54, 60, 67, 72, 77, 85, 91, 94, 95, 107, 110, 127, 128, 188, 192, 193, 197–199, 201, 202, 204, 206, 210, 217–219, 221, 222, 224–226, 230–235, 238–245, 249, 259, 261–263, 273, 278–281, 285, 289, 301–306, 308, 309, 312, 313, 315–317, 319, 322, 330, 331, 333–335, 337, 340, 351, 355, 360, 390, 402.
Trautschold, H., 152.
Verrill, A. E., 130.
Wachsmuth, C., 63, 65, 76, 146, 147, 156–182.
Wachsmuth and Springer, 24, 32, 39, 41, 42, 46–48, 54, 61, 62, 64–66, 75, 76, 86, 87, 149, 150, 152–157, 159–163, 165–171, 173–175, 177, 178, 180–184, 195, 217, 258, 371, 372.
Weinberg, A., 407–409, 415.
Weldon, W. F. R., 407.
Zittel, K., 25, 26, 47, 48, 51, 66, 142, 145, 147, 152, 157, 158, 160–163, 165, 170, 185–189, 191, 197, 213, 214, 223, 245, 248, 258, 270, 273, 274, 276, 402, 403.

GENERAL INDEX.

The figures in dark type indicate the page on which the genus or species is first described.

Abactinal side, 157, 158, 171.
Abactinal system, 156, 169, 172.
Actinal side, 156, 158, 171, 179.
Actinal system, 156, 169, 172, 178.
Actinocrinidæ, 61, 62, 86, 149, 158, 164–181.
Actinocrinus, 62–66, 156–158, 164–166, 169, 172, 174–180, 182, 183, 185, 192, 394.
rugosus, 75.
verneuilianus, 165.
Actinoidea, 186, 187, 190.
Actinometra, 33, 36, 59, 68, 74, 78, 85, 93, 95, 97, 102, 104, 111, 115, 121–123, 127, 143, 153, 154, 284, 291, 337, 377, 381–385, 411; arms of, 55–57, 60, 69, 70; digestive tube of, 91, 92; disk of, 69, 70, 85; geographical and bathymetrical distribution of, 136–141; mouth of, 69, 403; plexiform gland of, 103, 104.
bennetti, 55, 127, 337.
dissimilis, 110, 111.
fimbriata, 52.
jukesi, 67, 69, 85, 91, 130, 132, 133, 319, 337 (Pl. lv. fig. 1).
loveni, 132.
magnifica, 57, 69, 91, 113 (Pl. lvi. fig. 7).
meridionalis, 280, 337.
multiradiata, 49, 52, 337.
nigra, 96, 110, 120–122, 124, 416 (Pl. lxi. fig. 6).
nobilis, 55, 57, 69, 110, 111.
novæ-guineæ, 49.
parvicirra, 50, 52, 57, 67, 102, 103, 107, 120, 121, 124, 133, 283, 337, (Pl. lxi. figs. 2–5).
Actinometra pulchella, 91, 103, 104, 109, 137, 337 (Pl. lx. fig. 1; Pl. lxi. fig. 1).
robusta, 144.
schlegeli, 55.
solaris, 10, 49, 51, 52, 58, 91, 280.
stellata, 132, 319.
stelligera, 69, 70, 337 (Pl. lvi. fig. 8).
strota, 60, 67, 69, 85, 86, 129, 130, 133 (Pl. liv. figs. 10, 11; Pl. lv. fig. 2).
trachygaster, 127.
typica, 4, 10, 49, 51, 52, 337.
Actinozoa, 193.
Agassizocrinus, 132, 153, 213, 217, 319.
Agelacrinidæ, 194.
Agelacrinoidea, 192.
Agelacrinus, 85, 192.
Allagecrinus, 146, 147, 152, 158, 159, 169, 213.
austini, 37.
Ambulacra, 56, 57, 68–70, 78–85, 93, 127, 179–181; of Comatulæ, 83–85; of *Metacrinus*, 81, 82; of *Pentacrinus*, 78–80; subtegminal ambulacra of Palæocrinoids, 164, 179.
Ambulacral epithelium, 59, 93, 112, 113, 415.
Ambulacral groove; see Ambulacra and Food-groove.
Ambulacral nerve, 59, 70, 93, 96, 111–115, 118, 120, 408–416; of *Antedon eschrichti*, 112, 118, 411; of the Blastoidea, 413.
Ambulacral plates, 55, 63, 65, 74–85, 165, 174–181, 184.
Amphiura, 395, 396.
Anal appendage, 41–46, 371, 372.
Anal plate, 38, 73.
Anal series, 45, 372.
Anal tube, 69, 70, 81, 89.
Anambulacral plates, 57, 62, 76–78, 80–86, 165, 180, 184.

Anchylosis, 3, 37.
Ancyrocrinus, 19.
Antedon, 33, 36, 57, 68, 74, 94, 127, 129, 143, 144, 154, 237, 249, 268, 291, 376–385, 402–404; ambulacra of, 83–85; digestive tube of, 88, 89; disk of, 68, 84, 85; geographical and bathymetrical distribution of, 136–141; labial plexus of, 97–100, 404–407; plexiform gland of, 101, 102, 235.
acoela, 57, 83, 84, 93, 109, 110, 113, 128 (Pl. liv. figs. 1–4; Pl. lv. fig. 5).
angusticalyx, 57, 83, 84, 93, 109, 110, 113, 128, 135 (Pl. liv. fig. 5; Pl. lv. fig. 6).
antarctica, 92, 98.
basicurva, 84 (Pl. liv. fig. 9; Pl. lv. fig. 7).
campichei, 144.
carinata, 98, 109, 124, 130, 137, 235 (Pl. lx. fig. 2).
dentata, 36, 130, 137.
eschrichti, 10, 52, 55, 62, 67, 78, 83, 88, 90, 92, 93, 95–102, 109, 111, 112, 114, 118, 120, 122–124, 133, 137, 144, 153, 208–210, 319; ambulacral nerve of, 112, 118, 411; parambulacral network of, 123, 124, 416; radial blood-vessels of, 96; spongy organ of, 98, 99 (Pl. lix. figs. 6, 7; Pl. lx. figs. 3–6).
fluctuans, 280.
hageni, 36.
inaequalis, 83 (Pl. liv. fig. 8).
incerta, 57, 83 (Pl. liv. figs. 6, 7).
lusitanica, 315.
milleri, 73.
multiradiata, 84, 85 (Pl. lv. figs. 3, 4).
phalangium, 10, 36, 130, 318.
protecta, 58.
quadrata, 98, 99.
rhodanicus, 144.
rosacea, 49, 50, 52, 58, 67, 70, 86, 88, 93, 95–98, 100–102, 104, 107–112, 118, 120, 122, 124, 125, 127, 129, 130, 133, 134, 280, 304, 404, 411, 413; anal plate of, 73; calyx interradials of, 39; genital glands of, 109; labial plexus of, 98; plexiform gland of, 102, 104; spongy organ of, 100 (Pl. lvi. fig. 6; Pl. lix. fig. 5).
scrobiculata, 336.
spinifera, 277.
Antedonin, 129.
Anthodiata, 186, 190, 191.
Apical dome plates, 157, 167, 168; of Actinocrinidæ, 164, 167; of the Blastoidea, 164, 173; of Cyathocrinidæ, 164, 172; of *Glyptocrinus*, 184; of Ichthyocrinidæ, 181, 183; of *Periechocrinus*, 171, 172; of Platycrinidæ, 164, 175–178; of Rhodocrinidæ, 164; of *Strotocrinus*, 171, 172.
Apical system, 2, 157, 172, 393–402.
Apiocrinidæ, 32, 48, 54, 142, 183, 222, 225, 247, 286.
Apiocrinites, 245.
Apiocrinus, 8, 11, 25, 42, 49, 53, 68, 76, 125, 126, 135, 145–147, 150, 153, 154, 181, 183, 211, 223, 230, 249, 256, 270, 276, 289, 293, 340.
constrictus, 24, 257.
cornutus, 258.
crassus, 256.
insignis, 9.
magnificus, 256.
martini, 39.
milleri, 215.
murchisonianus, 256.
parkinsoni, 9, 131, 150.
roissyanus, 39, 149, 150, 183, 215.
Arm-groove, 64, 65, 77–83.
Arms, 47–56, 154, 194; of *Actinometra*, 55–57, 60, 69, 70; of *Bathycrinus*, 232, 233, 236; of Crinoids and Cystids compared, 189; of *Extracrinus*, 59–61, 224, 277, 278; of *Holopus*, 207–209; of *Hyocrinus*, 52, 53, 219, 224; of Pentacrinidæ, 55, 56, 154, 155, 277, 278, 284–287; of *Rhizocrinus*, 52–54, 64, 65, 267.
Article basal of *Apiocrinus* and *Bourgueticrinus*, 3, 25, 153, 257.
Articulata, 145, 182, 195, 196.
Articulation, bifascial, 8, 53, 231, 280, 304, 326, 329, 330; muscular, 9–11, 146, 194; trifascial, 8, 9, 53, 231–233.
Asterencrinidea, 187.
Asterias, 245, 395, 396, 399, 400.
Astrocrinidæ, 194.
Astrocrinus, 132.
Atelecrinus, 34, 36, 56, 58, 68, 127, 137, 138, 140, 141, 144, 291, 292, 294, 371.
balanoides, 376, 380.
cubensis, 379.
Axial cords of rays and arms, 31, 114–127, 146, 407–416; of *Bathycrinus*, 31, 119, 236; of *Holopus*, 119, 209, 236; of *Pentacrinus*, 124, 126, 293, 294; of *Rhizocrinus*, 119, 126, 252, 253.

Axillary, 9, 10, 33, 48, 58–61, 90, 125; of *Eudesicrinus*, 215; of *Holopus*, 204–206.
Avicula, 134, 369.
Balanocrinus, 143, 270–272, 287.
Barycrinus, 54, 61, 363.
herculeus, 61, 224.
Basals, 2, 3, 33–39, 71, 73, 106, 124–126, 157, 158, 168–172, 363, 393–399, 402, 403; of *Bathycrinus*, 37, 226–228; of Comatulæ, 34–36, 251, 284, 402, 403; of *Pentacrinus*, 34, 35, 282–284, 293, 336; of *Rhizocrinus*, 36, 248–253; of *Thaumatocrinus*, 34, 36, 371.
Basaltiformes, 296.
Bathycrinus, 38, 48, 54, 56, 58, 62, 91, 104, 117, 127, 143, 213, 214, 222, 223, 225, 226–238, 243, 248, 252, 254–256, 289–292, 386, 388, 391, 392; arms of, 232, 233, 236; axial cords of, 31, 119, 236; basals of, 37, 226–228; chambered organ of, 34, 107, 235; covering plates of, 74, 234; digestive tube of, 33, 89, 90, 236; disk of, 234, 235; genital glands of, 109; geographical and bathymetrical range of, 136–140, 391, 392; nerves in stem of, 31, 119; pinnules of, 233, 234; plexiform gland of, 89, 90, 101, 235; primary interradial cords of, 126, 228–230; radials of, 3, 37, 230, 231; stem of, 23, 24, 26–28, 226; trifascial articulations of, 8, 9, 53, 231–233; stem of, 23, 24, 26–28, 226; vascular axis in stem of, 107, 235; visceral mass of, 33, 90, 234; water-tubes of, 93, 236.
aldrichianus, 8, 10, 31, 37, 71, 119, 120, 130, 134, 225–235, 237–240, 241, 242, 243, 244, 376, 386, 389, 391 (Pl. vii.; Pl. viia. figs. 1–21; Pl. viib.; Pl. viiia. figs. 4, 5).
campbellianus, 227, 232, 233, 235, 237, 238, 239, 240, 242, 376, 386, 389, 391 (Pl. viia. figs, 22, 23; Pl. viii.).
carpenteri, 8, 71, 226, 227, 231–234, 237, 244, 386, 389, 391.
gracilis, 71, 227, 231, 232, 235, 237, 238, 243, 244, 245, 374, 386, 389–391 (Pl. viiia. figs. 1–3).
Bathymetrical range of Crinoids, 137, 138.
Belemnocrinus, 38, 151, 217, 258, 259.
florifer, 259, 270, 363.
pourtalesi, 259.
Blastactinota, 190.
Blastoidea, 54, 68, 75, 109, 132, 148, 149, 154, 164, 173, 175, 186, 188–195, 413, 414.
Blood-vascular ring, 1, 96, 105, 106, 407.
Blood-vascular system, 96–109, 405–407.
Blood-vessel, intervisceral, 87, 97–105, 405, 406; radial, 1, 59, 70, 92, 93, 96, 97, 100.
Bôtryocrinus, 61.
Bourgueticrinidæ, 142, 225, 269, 290, 386; calyx of, 33; stem of, 6, 7, 23–31, 131.
Bourgueticrinus, 24, 142, 143, 154, 222, 225, 237, 245–249, 254–258, 270, 276, 323, 392.
æqualis, 256.
alabamensis, 143, 257.
didymus, 258.
ellipticus, 24, 256.
hofessieri, 246, 259.
londinensis, 257, 269.
ooliticus, 257.
suessi, 248, 257.
thoventi, 247, 258.
Brachiata, 186, 187, 191.
Briaraden, 276, 278, 296.
Brisinga, 398–400.
Cainocrinus, 35, 272, 273, 281–283.
Callicrinus, 157, 400.
Calyx, 33–46, 124–126, 393, 394; of *Bathycrinus*, 37, 226–231; of *Cotylecrinus*, 213, 214; of *Cyathidium*, 211, 212; of *Eudesicrinus*, 215; of *Extracrinus*, 274–276; of *Holopus*, 33, 36, 199–204, 213; of *Hyocrinus*, 33, 36, 218, 223; of Pentacrinidæ, 33, 291–294; of *Rhizocrinus*, 3, 29, 33, 34, 36, 38, 248–253, 257.
Canaliculata, 196.
Carpocrinus ornatus, vault of, 180, 181.
Caulaster, 195, 399, 401, 402.
Cenocrinus, 273, 278–281, 334.
caput-Medusæ, 301.
Central capsule, 410–414, 416.
Centro-dorsal of Apiocrinidæ, 25; of Comatulæ, 25, 106, 107, 132, 292; of *Cotylecrinus*, 213–215.
Ceriocrinus, 46.
Chambered organ, 15, 23, 33, 104–108, 114, 119, 194, 404–406; of *Bathycrinus*, 34, 107, 235; of Comatulæ, 106, 107, 292, 404, 412; of *Pentacrinus*, 105, 292, 412.
Chelocrinus, 295.
acutangulus, 294.
Chladocrinus, 271, 272.

Circular commissure, 40, 117, 413; of *Bathycrinus*, 126, 228–230; of Comatulæ, 125; of *Pentacrinus*, 125; of *Rhizocrinus*, 126, 253.
Circumvisceral coelom, 67.
Cirri, 7, 107, 108, 114, 132, 414; of Bourgueticrinidæ, 27, 28; of Comatulæ, 132, 414; of Pentacrinidæ, 12, 288, 342.
Cirrus-vessel, 15, 23, 107, 292, 412.
Clypeaster, 394.
Coccocrinus, vault of, 160–163, 170, 174, 175, 178, 185.
Comaster, 151, 403.
Comatula, 3, 4, 6, 8–10, 18, 19, 22, 24, 25, 33–36, 38, 40, 44, 45, 48–53, 55, 56, 58, 59, 62, 63, 68, 70–74, 76, 78, 83–85, 88, 90, 91, 93–95, 97, 106, 107, 110, 117, 119, 124, 125, 130–135, 144–148, 154–156, 164–166, 169, 175, 177, 181, 183–185, 192, 230, 249, 252, 254, 255, 261, 273, 277, 279, 285–287, 289–294, 316, 319, 324, 326, 337, 340, 363, 370–372, 393, 401, 412, 413, 415.
Ambulacra of, 68, 156; ambulacral plates of, 62, 74, 83, 84, 175, 181; arms of, 52, 55, 147, 337; axial cords of, 119, 121–123, 408, 409; basals of, 34–36, 251, 284, 402, 403; centro-dorsal of, 25, 106, 107, 132, 292; chambered organ of, 106, 107, 292, 404, 412; circular commissure of, 125; cirri of, 132, 414; disk of, 68–70, 84, 85, 90; geographical and bathymetrical distribution of, 136–141; monstrosities of, 70; oral plates of, 71, 72, 156; pinnules of, 58, 59, 83; radials of, 147, 289, 293, 294; reparation of, 60, 255; syzygies of, 4, 53.
Comatulidæ, 142, 192, 370.
Conocrinus, 245, 247, 248.
cornutus, 258.
pyriformis, 248, 257.
seguenzai, 257.
suessi, 257.
Consolidating plates of *Cupressocrinus*, 162.
Convoluted organ of Actinocrinidæ, 87, 165.
Costal plates, 396–399.
Costata, 190, 195.
Cotylecrinus, 68, 143, 161; systematic position, 213–217.
docens, 213.
miliaris, 214.
Cotylederma, 213.
Covering plates, 62–66, 74–83, 115, 166, 173–175, 181, 185, 220.
Crinactinota, 190, 191.
Crinoidea, 186, 187, 188–195.
Crotalocrinus, 54, 65, 66, 157.
pulcher, 65.
Culicocrinus, summit plates of, 170, 175.
Cupressocrinus, 48, 150, 152, 153, 162.
Cupule of *Cotylecrinus*, 213, 214.
Cyathidium, 143, 202; systematic position, 211–216.
spileccense, 212.
Cyathidiocrinidæ, 211.
Cyathocrinidæ, 153, 155, 160, 162, 164, 173, 181.
Cyathocrinus, 44, 45, 48, 60–66, 146, 151, 154, 161–164, 169, 173–175, 178, 185, 224, 394–398.
alutaceus, summit of, 173.
iowensis, ambulacra of, 65.
lævis, summit of, 173.
longimanus, ambulacra of, 65, 66, 84.
malvaceus, summit of, 172.
ramosus, ambulacra of, 66.
Cycloblastus, 191.
Cyclocystoides, 192.
Cystidæ, 192.
Cystidea, 54, 109, 132, 148, 149, 154, 186, 188–195.
Cystoblastus, 191.
Cystoidea, 186, 195.
Deltoid pieces of the Blastoidea, 162.
Democrinus, 28–30, 245, 264, 268, 269.
parfaiti, 262, 264, 269.
Dendrocrinus casei, 45.
navigiolum, 20.
Dichocrinus, 39, 222, 223.
intermedius, 223.
Digestive tube, 1, 84, 86–92.
Disk, 1, 67, 75, 80, 81, 84, 85, 88, 90, 182, 184, 342; of *Actinometra*, 69, 70, 85; of *Antedon*, 68, 84, 85; of *Bathycrinus*, 234, 235; of *Hyocrinus*, 219; of *Metacrinus*, 59, 68, 80, 81, 93, 342; of *Pentacrinus*, 68, 76, 77, 91, 279.
Distichals, 49, 50, 177.
Dorsocentral, 18, 132, 157, 158, 168, 169, 274, 275, 393–396, 398–400.
Echinosphærites, 192, 195.
Echinozoa, 95, 105, 106, 193, 194, 406.
Edrioaster, 192.
Edriocrinus, 143, 194, 195, 217, 319.
Eleacrinus, 164, 173.
Eleutherocrinus, 132.

Emedullata, 151, 196.
Encrinidæ, 142, 187.
Encrinites dubius, 294.
Encrinus, 25, 34, 35, 48, 49, 51, 117, 125, 126, 142, 143, 145, 149, 150, 152–155, 230, 272, 275, 284, 294–296, 300, 340, 363, 394, 395.
beyrichi, 270, 295.
caput-Medusæ, 274, 300.
gracilis, 37, 153.
liliiformis, 294.
pentactinus, 295.
Epizygal, 4, 50, 219.
Erisocrinus, 150, 152–154.
Eucalyptocrinus, 151, 157, 160, 195, 400.
crassus, root of, 20.
Eucrinoidea, 186–189.
Eudesicrinus, 19, 143, 149, 161, 202, 205; systematic position of, 213–216.
Eudiocrinus, 36, 47, 58, 68, 137, 138, 140, 143, 291, 373.
atlanticus, 47, 127.
indivisus, 47, 48, 58, 127, 137.
japonicus, 47, 109, 127, 339, 378.
semperi, 36, 47, 127.
varians, 47, 58, 127.
Eugeniacrinidæ, 142, 216.
Eugeniacrinites, 245.
Eugeniacrinus, 68, 131, 142, 161, 211, 214, 227, 247, 248.
mayalis, 215.
pyriformis, 247.
Eupachycrinus, 46, 153, 154.
Extracrinus, 8, 30, 34, 41, 43, 51, 59–61, 76, 131, 143, 145, 149, 150, 154, 181–183, 271, 272, 274–278, 281, 288, 296–299, 308, 371, 394, 395; arms of, 59–61, 224, 277, 278; calyx of, 274–276; geological range of, 296–298; stem of, 276, 277, 287.
bridreus, 20, 22, 54, 55, 81, 131, 274, 275, 278, 296, 297, 313.
subangularis, 16, 22, 30, 54, 274, 277, 413.
Food of Crinoids, 132, 133.
Food-grooves, 56, 64, 68, 69, 77–85, 92, 156, 163–166, 173, 180, 236, 415.
Free rays of Ichthyocrinidæ, 181; of *Platycrinus*, 177.
Genital canal, 96, 209.
Genital cord, 61, 63, 108, 110, 111, 209, 210.
Genital glands, 56, 57, 61, 63, 83, 108–111, 220.
Genital plates of Echini, 2, 168, 169, 172, 393–398, 402.
Genital vessels, 97–100, 105, 108, 109.
Geographical range of Crinoids, 136, 137.
Gissocrinus, 66, 174.
punctuosus, ambulacra of, 65.
Glyptocrinus, 183–185.
decadactylus, 183.
schafferi, 20.
Glyptocystites, 20.
Goniaster, 245.
Growing point of arms, 56, 59, 60, 400.
Guettardicrinus, 39, 146, 149–152, 181, 289.
Gymnocrinus, 143, 216.
Habits of Crinoids, 130–132.
Habrocrinus, 66, 180.
Haplocrinus, 54, 157–159, 163, 164, 167, 170, 171.
mespiliformis, 158.
Heterocrinus, 42, 45, 53, 154, 267, 363.
constrictus, 53, 224.
simplex, 53, 224.
Hexacrinus, 39, 176, 217.
Holopidæ, 197, 216, 386.
Holopocrinidæ, 211.
Holopodidæ, 142, 143, 195, 217.
Holopus, 38, 48, 127, 131, 141, 143, 145, 149, 155, 159–161, 172, 185, 197, 198–217, 386, 388.
Arm-joints of, 207, 209; axial cords of, 119, 209, 236; bivium and trivium of, 202, 207; calyx of, 33, 36, 199–204, 213; colouring matter of, 129, 204, 210; genital glands of, 63, 110, 210; geographical and bathymetrical distribution of, 136–138, 140, 141; oral plates of, 70, 72, 95, 156, 198, 208; pinnules of, 207, 208; second and axillary radials of, 204–206; systematic position of, 211–217; tentacles of, 208.
rangi, 199–208, 380, 381, 384, 385, 386, 388, 389 (Pls. i.–vb.; Pl. vc. figs. 1–3).
Hybocystites, 191.
Hydrospires of Blastoidea and Cystidea, 194.
Hyocrinidæ, 31, 217, 223, 386.
Hyocrinus, 48, 54, 60–62, 73, 83, 134, 142, 146, 149, 155, 160, 161, 176, 179, 181, 185, 208, 217, 218, 219, 221, 222, 234, 236, 242, 267, 289, 371, 386, 388, 391, 392; arms of, 52, 53, 219, 224; calyx of, 33, 36, 218, 223; covering plates of, 74, 220; genital glands of, 109, 220; geographical and bathymetrical distribution of, 137–140;

Hyocrinus continued—
oral plates of, 70, 72, 94, 95, 156, 219; pinnules of, 59–61, 219, 224; side plates of, 82, 220; stem of, 5, 31, 32, 218, 221; systematic position of, 222–224; testes of, 220; water-pores of, 94, 95, 219, 220.
bethellianus, 218–222, 240, 376, 378, 386, 389, 391 (Pl. vc. figs. 4–18; Pl. vi.).
Hyponome sarsi, 67, 85, 166.
Hypozygal, 4, 50, 54.
Ichthyocrinidæ, 42, 76, 149, 155, 166, 181–185, 195.
Ichthyocrinus, 185, 195.
Ilyaster, 401.
Ilycrinus, 225.
Inarticulata, 145.
Infra-nodal joint, 13.
Interarticular pores, 18.
Internal casts of Actinocrinidæ, 165, 174, 179, 182; of *Platycrinus*, 179.
Interpalmar areas of disk, 69, 81, 84, 165, 166, 174, 180.
Interradials of calyx, 38–46, 74, 162, 178, 371.
Interradials of perisome, 42–44, 73, 74, 76, 183, 371.
Intervisceral blood-vessels, 87, 97–105, 405, 406.
Intervisceral coelom, 67, 109.
Intervisceral plexus, 86, 87.
Intra-radial commissure of *Comatula* and *Pentacrinus*, 125, 126; of *Bathycrinus*, 127, 229; of *Rhizocrinus*, 126, 253.
Iocrinus, 46, 363.
Isis, 272, 300, 302.
Isocrinus, 271–273, 281.
pendulus, 34, 284.
Labial plexus, 93, 97–101, 103–105, 404–406.
Lecanocrinus rœmeri, 217.
Lepidodiscus, 85.
Lichenocrinoidea, 192.
Lichenocrinus, 192.
dubius, 20.
Ligaments, of arms, 7–9, 414; basiradial ligaments of *Bathycrinus*, 228; of stem, 5–7, 13, 23.
Madreporic canal of Echinozoa, 106, 194, 406.
Maviacrinus, 155, 171.
Marsupiocrinus, vault of, 171, 175–177
depressus, 176.
radiatus, 176.
Marsupites, 34, 48, 68, 132, 142, 145, 151, 155, 181, 183, 196, 216, 394–398.
Marsupitidæ, 142.
Megistocrinus, 54.
Mesocrinus, 24, 237, 255–257, 323.
Metacrinus, 10, 13, 110, 124, 128, 134, 148, 152, 154, 205, 270–272, 275, 283, 285–288, 291, 300, 304, 311, 320, 334, 336, 339, 340, 341–344, 357, 359, 360, 362, 369, 370, 387, 388–391; arms of, 55, 285, 286, 342; cirri of, 288, 342; disk of, 59, 68, 80, 81, 93, 342; geographical and bathymetrical distribution of, 136–142, 343; pinnules of, 10, 55, 58, 155, 341, 342; pinnule-ambulacra of, 81, 82; radials of, 48 51, 341, 357; stem of, 14, 15, 17, 19, 287, 288, 342, 343.
angulatus, 19, 51, 60, 70, 80, 81, 110, 134, 287, 288, 293, 342, 344, 345, 346, 348, 355, 357, 364, 366, 369, 370, 377, 387, 389 (Pl. xii. figs. 1–14; Pls. xxxviii., xxxix.).
cingulatus, 17, 80, 81, 287, 288, 342, 344, 346, 347, 348, 355, 357, 358, 369, 377, 387, 389 (Pl. xl.; Pl. xli. figs. 1–4).
costatus, 17, 35, 82, 129, 284, 288, 342, 344, 359, 360–362, 363–366, 368–370, 378, 387, 389 (Pl. xlvii. fig. 13; Pl. xlix.).
Metacrinus dredged by the "Vega," 340, 343, 344, 368, 387, 388.
interruptus, 134, 288, 342–344, 367, 368, 369, 377, 387, 388 (Pl. lii.).
moseleyi, 17, 129, 341, 344, 355, 356, 357–359, 378, 387, 389 (Pls. xlv., xlvi.).
murrayi, 17, 78, 81, 82, 128, 140, 184, 326, 342–344, 349, 350, 351, 352, 355, 377, 378, 387, 389 (Pl. xli. figs. 12–17; Pl. xlii.).
nobilis, 17, 80–82, 287, 344, 350, 351, 352, 353, 355, 369, 377, 387, 389 (Pl. xli. figs. 5–11; Pl. xliii.).
nodosus, 51, 76, 80–82, 289–291, 342, 344, 359, 362, 364, 365, 366, 368–370, 377, 387, 389, 391 (Pls. l., li.).
rotundus, 343, 344, 357, 387, 388.
stewarti, 288, 344, 387.
superbus, 344, 351, 352, 355, 387.
tuberosus, 134, 288, 342, 344, 369, 370, 377, 387, 389 (Pl. liii. figs. 1–6).
varians, 17, 129, 134, 288, 342, 344, 351, 352, 353, 354, 355, 366, 378, 387, 389 (Pl. xliv.; Pl. xlvii. figs. 6–12).

Metacrinus wyvillii, 129, 136, 288, 342–344, 354, 357, 358, 359, 360, 362–365, 368, 377, 378, 387, 389, 391 (Pl. xlvii. figs. 1–5; Pl. xlviii.).
Micropocrinus, 143, 216.
Millericrinus, 8, 11, 25, 49, 54, 131, 135, 153, 256, 270, 271, 281, 282, 340.
nodotianus, 256.
pratti, 20, 26, 51, 132, 328.
simplex, 256.
Monstrosities, 70, 347.
Mouth, 56, 68–70, 91, 103, 156, 166, 403.
Mouth-shields of Ophiurids, 2, 169.
Muscles, 9–11, 113–115, 414, 415.
Myelodactyloidea, 192, 193.
Myelodactylus, 192, 193.
Myrtillocrinus, 146.
Myzostoma, 70, 133–135, 324, 358, 364, 369.
deformator, 324.
pentacrini, 324, 364.
wyville-thomsoni, 347, 362, 364.
Neocrinoidea, 9, 38, 49, 51, 59, 142, 145, 147–157, 160–162, 170–173, 181, 185, 194, 195, 196, 217, 224, 270, 295, 309, 411.
Neocrinus, 273, 279, 280, 302, 334.
Nerve-fibres of stem, 23, 31, 116, 119, 120.
Nervous system, 111–127, 407–416.
Neuro-vascular axis of stem, 194, 413.
Nodal joints in stem of Pentacrinidæ, 4, 12–15, 17, 19, 105, 107, 291.
Ocular plates of Echini, 2, 168, 169, 393, 394, 402.
Odontophore of Starfishes, 2, 398–400.
Ollacrinus, 157.
Onychocrinus, 41, 42, 151, 181, 182, 372.
Oral pinnules of *Antedon*, 59, 115.
Oral plates, 2, 70, 73, 94, 95, 156–164, 167–173, 178, 184, 185, 398; of *Bathycrinus*, 234; of *Comatula*, 71, 72, 156; of *Holopus*, 70, 72, 95, 156, 198, 208; of *Hyocrinus*, 70, 72, 94, 95, 156, 219; of *Rhizocrinus*, 70, 72, 156, 219, 255; of *Thaumatocrinus*, 70, 72, 160, 161, 371.
Orocentral, 158, 159, 167–172, 178, 184.
Ovary, 109–111, 210.
Ovoid gland, 104–106, 406, 407.
Palæocrinoidea, 32, 38, 39, 47–49, 54, 61, 68, 72, 132, 135, 147–158, 164–167, 172, 173, 181, 185, 194, 195, 217, 218, 224, 270, 271, 295, 358, 363, 370–372, 394.
Palæostoma mirabilis, 2.
Parambulacral network, 123, 124, 415, 416.
Parasites of Crinoids, 133–135.
Palma animal, 301.
Palmars, 49, 177.
Palmier marin, 300.
Pelmatozoa, 186, 187, 188, 190, 191, 193–195, 413.
Pentacrinidæ, 56, 71, 83, 110, 119, 125, 132, 142, 143, 146, 150, 154, 156, 166, 183–185, 192, 228, 270, 271, 277, 289–291, 294, 295, 310, 317, 320, 322, 323, 326, 337, 386.
Ambulacral skeleton of, 62, 74–82; arms of, 55, 56, 154, 155, 277, 278, 284–287; calyx of, 33, 291–294; characters of young, 289–291, 327; cirri of, 12, 288, 342; colouring matter of, 128, 129, 210; colonies of, 130, 131; disk interradials of, 73, 76, 183; ovaries of, 110; parasites of, 134, 135; pinnules of, 55, 58, 59, 155, 286; stem of, 3–6, 12–23, 287, 288, 290, 291, 315–319, 342, 343; syzygies of, 4, 5, 254, 326.
Pentacrinin, 128, 129; 204, 210.
Pentacrinites, 272, 273.
vulgaris, 274, 300.
Pentacrinoid larva of *Comatula*, 24, 39, 70, 89, 93, 95, 101, 107, 108, 116, 127, 158, 159, 161, 164, 194, 214, 219, 237, 251, 290, 396.
Pentacrinus, 3, 7–10, 13, 17–19, 49, 50, 53, 58, 62, 66, 74, 76–81, 84–88, 90, 97, 101, 103, 104, 110, 117, 126, 127, 128–132, 134–141, 143, 145, 148, 155, 165–167, 173, 181, 182, 192, 195, 210, 211, 228–231, 235, 244, 252, 256, 259, 261, 271, 272, 273, 274–300, 302–304, 316–320, 326, 340–343, 364, 369, 386, 388, 391, 392, 394, 409, 415.
Basals of, 34, 35, 282–284, 293, 336; chambered organ of, 105, 292; disk of, 68, 76, 77, 91, 279; geographical and bathymetrical distribution of, 136–141, 300, 343, 391, 392; geological history of, 294–300; intervisceral blood-vessels of, 101, 102; labial plexus of, 93, 100; plexiform gland of, 105; primary interradial cords of, 124–126, 292, 293; radials of, 289, 293, 294; radial plug of, 34, 293; stem of, 12–23, 287, 288, 315–319, 342, 343; vascular axis in stem of, 23, 107; water-vascular ring of, 93.

Pentacrinus alternicirrus, 12, 19, 21, 44, 55, 77, 78, 80, 128, 135, 136, 177, 184, 277, 282, 284–286, 288, 293, 299, 305, 310, 313, 315, 318, 320, **321**, **322**, 323, 324, 326, 335, 337, 346, 353, 364, 377, 378, 386, 389, 391, 412 (Pls. xxv., xxvi.; Pl. xxvii. figs. 1–10).
asteriscus, 143, 297, 298.
astexius, 4, 14, 17, 19, 42, 58, 64, 73, 74, 79, 154, 183, 184, 274, 275, 277, 279, 280, 282, 283, 285–288, 293, 299, 300, **301**, **302**, 303–305, 308–312, 318, 329, 332–335, 342, 343, 371, 381, 384, 386, 388, 389 (Pl. xi.; Pl. xii. figs. 15–25; Pl. xiii.; Pl. xvii. figs. 7, 8).
basaltiformis, 300.
beaugrandi, 286.
blakei, 5, 14, 35, 50, 78, 280, 283, 284, 287, 288, 299, 319, 326, **328**, **329**, 330, 334, 342, 381–383, 386, 389 (Pls. xxxi., xxxii.; Pl. xxxiii. figs. 1–3).
briareus, 274, 278, 280, 297, 302.
briareus achalmianus, 297.
briareus minutus, 278.
briareus zollerianus, 297.
bronnii, 323.
buchsgauensis, 297.
caput-Medusæ, 274, 278, 281, 300–302, 304, 306, 308, 309.
darguiesi, 297.
decorus, 14, 18, 21, 35, 50, 51, 60, 77, 79, 91, 93, 95, 96, 100–102, 104, 105, 120, 123, 231, 279, 280, 283–285, 288, 290, 291, 293, 294, 299, 303–305, 308–312, 316, 319, 320, 324, 326, 329, 330, **331**, **332**, 333–337, 341, 342, 379–386, 388, 389, 402, 416 (Pl. xxxiii. figs. 4–6; Pls. xxxiv.–xxxvii.; Pl. lvii. figs. 2–5; Pl. lviii. figs. 1–3; Pl. lix. figs. 1–4; Pl. lxii.).
didactylus, 323, 327.
dixoni, 143, 284.
dubius, 294, 295.
fisheri, 34, 143, 284.
jaccardi, 17.
johnsoni, 274.
jurensis, 4.
Pentacrinus maclearanus, 15, 19, 20, 35, 55, 62, 80, 277, 281, 282, 284, 285, 288, 299, 310, **312**, **313**, 315, 318, 323, 343, 346, 353, 376, 387, 389, 412 (Pl. xvi.; Pl. xvii. fig. 1).
milleri, 274.
mollis, 44, 300, **338**, **339**, 343, 378, 387, 389, 391 (Pl. xxxiii. figs. 7–10).
mülleri, 14, 51, 55, 61, 77, 80, 277, 280, 285, 288, 299, 304, 305, **306**, **307**, 308–313, 315, 316, 318, 320, 323, 324, 330, 331–334, 337, 340–342, 380–385, 387–389 (Pls. xiv., xv.; Pl. xvii. figs. 9, 10).
naresianus, 5, 14, 18, 21, 44, 50, 52, 53, 77, 78, 94, 128, 136, 140, 143, 184, 231, 240, 275, 280, 285–288, 290, 291, 293, 299, 300, 320, 322, **324**, **325**, 326–330, 334, 336, 337, 342, 354, 377, 378, 387, 389, 391 (Pl. xxvii. figs. 11–13; Pls. xxviii.–xxx.).
nicoleti, 17.
nodotianus, 297.
pentagonalis personatus, 34, 284.
psilonoti, 300.
scalaris, 4, 35, 284.
sigmaringensis, 300.
subangularis, 274, 278.
subteres, 270.
tridactylus, 323.
tuberculatus, 35, 274, 286.
vulgaris, 294.
wyville-thomsoni, 14–17, 19, 21, 35, 44, 55, 76–78, 80, 91, 93, 98, 100, 119, 124, 129, 130, 136, 176, 185, 277, 280–284, 286–288, 290, 291, 293, 294, 299, 305, 310, 313, **314**, 315–320, 322, 323, 335, 337, 342, 343, 346, 375, 387, 389–391, 415 (Pl. xvii. figs. 2–6; Pls. xviii.–xxiv.; Pl. lvii. fig. 1).
Pentremites, 192, 195, 413, 414.
Pentremitidæ, 192.
Periechocrinus, summit of, 171, 172.
Perisomatic skeleton, 1, 2, 73–85, 182.
Perisome, 67, 68, 97.
Perisomic plates, 39, 40, 41, 124.
Peristome, 68, 71, 84, 87, 164, 179, 181.
Peritoneum, 67, 99, 100.
Philocrinus, 152–154.
Phimocrinus, 150.

Phyllocrinus, 142, 216, 227, 413.
Physetocrinus, summit of, 171.
Pigment, 23, 97.
Picteticrinus, 273, 281.
Pinnastella, 187.
Pinnigrada, 187, 190.
Pinnules, 55–66, 174; of *Bathycrinus*, 233, 234; of Comatulæ, 58, 59, 83; of *Holopus*, 207, 208; of *Hyocrinus*, 59–61, 219, 224; of *Metacrinus*, 10, 55, 58, 155, 341, 342; of *Pentacrinus*, 55, 58, 59, 155, 286; of *Rhizocrinus*, 56, 60, 255.
Pisocrinus, 48, 54.
Platycrinidæ, 61, 62, 149, 158, 160, 162, 167, 168, 170, 171, 175, 176, 178–181.
Platycrinus, 24, 48, 62, 65, 146, 151, 155, 163, 164, 174, 176–179, 185, 196, 217, 223, 237, 258, 394.
burlingtonensis, 177.
ventricosus, 170.
Pleurocystites, 20.
Plexiform gland, 33, 34, 96–106, 108; of *Actinometra*, 103, 104; of *Antedon*, 101, 102, 235; of *Bathycrinus*, 89, 90, 101, 235; of Echinozoa, 101, 105, 407; of *Pentacrinus*, 105; of *Rhizocrinus*, 89, 101, 104.
Plicatocrinidæ, 142, 222.
Plicatocrinus, 49, 51, 142, 152, 155, 205, 214, 222, 223, 289.
Poteriocrinus, 46, 60, 61, 146, 224, 394.
radiatus, 152.
Primary interradial cords, of *Bathycrinus*, 126, 228–230; of *Encrinus*, 125, 126; of *Pentacrinus*, 124–126, 228, 230, 292, 293; of *Rhizocrinus*, 126, 228–230, 252, 253.
Proboscis, 41–44, 87.
Promachocrinus, 36–38, 68, 90, 92, 97, 137, 138, 140, 144, 216, 403.
abyssorum, 376, 377.
kerguelensis, 98, 99, 101, 102, 127
naresi, 378.
Proximal plates of vault, 168–172.
Psolidæ (orals of), 2.
Pterocrinus, 242, 243.
Pterotocrinus, 157, 177.
Radials (first), 2, 3, 33–38, 48, 106, 152, 155, 157, 168–170, 393–395, 399, 402; of *Bathycrinus*, 3, 37, 230, 231; of Comatulæ, 147, 289, 293, 294; of *Metacrinus*, 48–51, 341, 357; of *Pentacrinus*, 289, 293, 294; of *Promachocrinus*, 37, 38; of *Rhizocrinus*, 250–253.
Radials (second), 38, 47, 50; of *Eudesicrinus*, 10, 215; of *Holopus*, 204–206, 215; of *Metacrinus*, 48, 341.
Radial dome plates, 167, 169, 175–178.
Radial plug, 34, 293.
Radial skeleton, 1, 2.
Radial spaces, 31, 32.
Radicular cirri, 27, 28.
Ray-divisions, 47–51, 337.
Reparation of arms, 60, 255, 285; of disk, 255.
Reteocrinus, 42, 151, 181, 183–185, 371, 372.
nealli, 43, 44, 184.
richardsoni, 43.
stellaris, 43.
subglobosus, 43.
Rhizocrinus, 3, 24, 27–31, 38, 54, 64, 73, 109, 127, 130, 132, 142, 143, 151, 153, 213, 217, 222–226, 229–238, 244, 245, 246, 247–259, 268, 269, 289–292, 317, 371, 388, 391, 392; ambulacral plates of, 62, 261; arms of, 52–54, 64, 65, 267; calyx of, 33, 34, 36, 38, 248–253, 257; digestive tube of, 88–90, 254; geographical and bathymetrical range of, 136–141, 391, 392; intra-radial commissure of, 126, 253; orals of, 70, 72, 156, 219, 255; parasites of, 134; pinnules of, 56, 60, 255; plexiform gland of, 89, 101, 104; primary interradial cords of, 156, 228–230, 252, 253; reparation of disk in, 255; second brachials of, 38, 254; stem of, 23–31, 107, 256; syzygies of, 5, 9, 254, 255; visceral mass of, 33, 90, 254, 255.
lofotensis, 3, 25–28, 36, 47, 56, 72, 90, 93, 134, 136, 246, 248–251, 253, 254, 257, 259, 260, 261–266, 268, 374–376, 378–380, 382, 384, 386, 388, 389, 391 (Pl. viiia. figs. 6–8; Pl. ix. figs. 1, 2; Pl. x. figs. 1, 2).
londinensis, 269.
rawsoni, 25, 28–30, 47, 56, 72, 134, 249, 254, 255, 257, 258, 262, 263–269, 374–376, 379–384, 386, 388, 389, 391 (Pl. ix. figs. 3–5; Pl. x. figs. 3–20; Pl. liii. figs. 7, 8).
calyx of, 265–267; pinnules of, 267; young specimens of, 264, 265.
Rhodocrinidæ, 39, 40, 149, 164, 167, 168, 171, 174, 371.
Rhodocrinites, 39, 40, 371.

Rhodocrinus, 371, 394.
Root-joint of stem, 28.
Rosette of Comatulæ, 34, 36, 106, 251, 291, 402; of *Rhizocrinus*, 34, 249, 251, 253.
Saccosoma, 190, 195.
Sacculi, 83, 127.
Salenia, 395.
Saumplättchen, 66, 74, 173, 174, 180.
Scalpellum, 369.
album, 134.
balanoides, 134, 351, 355.
Semiarticulata, 145.
Side plates, 62, 66, 74, 79–83, 165.
Solanocrinites, 272.
Solanocrinus, 402, 403.
Spongy organ, 98–101, 103, 406.
Stelidiocrinus, 180.
capitulum, summit of, 171.
Stem, 5–7, 12–32, 54, 114, 135, 194, 401; of *Bathycrinus*, 23, 24, 26–28, 226; of *Extracrinus*, 276, 277, 287; of *Hyocrinus*, 5, 31, 32, 156, 218, 221; of *Metacrinus*, 14, 15, 17, 19, 287, 288, 342, 343; of *Pentacrinus*, 12–33, 287, 288, 315–319; of *Rhizocrinus*, 23–31, 107, 256.
Stemmatocrinus, 150, 152–154.
Stilasteritæ, 187.
Stomatocrinoidea, 147, 156, 195, 196.
Strotocrinus, vault of, 171, 172.
Stylifer, 134.
Stylina, 134.
Subambulacral plates, 75, 85, 165.
Subangularen, 276, 278, 296.
Support of *Eudesicrinus*, 214–216.
Supra-nodal joint, 14.
Symbathocrinus, 54, 158, 163, 164, 167, 169–171, 179.
Synostosis, 2, 3.
Syzygial interval, 52.
Syzygy, 3–5, 8, 9, 15, 50, 52, 53, 231–233; of *Comatula*, 4, 53; of Pentacrinidæ, 4, 5, 254, 326; of *Rhizocrinus*, 5, 9, 254, 255.
Talarocrinus, vault of, 177.
Taxocrinus, 41, 42, 150, 151, 154, 211, 372.
Tentacles, 56, 57, 63, 69, 75, 93, 115, 117, 189, 194, 416; of *Holopus*, 208.
Tentaculata, 186, 189.
Tegmen calycis. See Vault.
Termination of stem in Pentacrinidæ, 18–23, 315–319.
Tessellata, 142, 145–148, 191, 195, 196.
Testes of *Hyocrinus*, 220.
Tetracrinus, 216, 227.
Thaumatocrinus, 33, 34, 36, 39–42, 44, 45, 47, 58, 68, 70–72, 127, 144, 148–151, 156, 160, 166, 172, 179, 185, 223, 291, 370, 371, 372, 392; anal appendage of, 41, 45, 371–372; basals of, 34, 36, 371; calyx interradials of, 39–41, 371; geographical and bathymetrical distribution of, 137 140; oral plates of, 70, 72, 160, 161, 371.
renovatus, 149, 372, 373, 377 (Pl. lvi. figs. 1–5).
Thiollericrinus, 24, 143, 257.
Thylacocrinus, 371.
Tiarechinus princeps, 414.
Torynocrinus, 142.
Uintacrinidæ, 142.
Uintacrinus, 132, 142, 147–151, 196.
Under-basals, 152, 153, 168, 169, 394–399, 402.
Ungrooved arms of *Actinometra*, 56, 57, 69, 70, 113, 115.
Vascular axis of stem, 15, 23, 104, 107, 235.
Vault, 41, 42, 156, 157, 166–168, 185; of Actinocrinidæ, 164–167, 173, 180, 181; of Blastoidea, 173; of *Coccocrinus*, 160–163; of Cyathocrinidæ, 173, 181; of *Glyptocrinus*, 183, 184; of Ichthyocrinidæ, 181, 182; of Platycrinidæ, 170, 171, 175–181; of *Reteocrinus*, 184; of *Xenocrinus*, 185.
Vegetative system, 54–56.
Ventral radial furrow, 252.
Ventral sac, 44, 46, 76.
Verruca, 349, 353, 355, 369.
nitida, 134.
Visceral mass, 1, 33, 67–70, 164, 166; of *Bathycrinus*, 33, 90, 234; of *Rhizocrinus*, 33, 90, 254, 255.
Visceral skeleton, 85–87.
Water-pores, 73, 75, 76, 81, 84, 92–96, 106, 194, 219, 220, 404–406.
Water-tubes, 92–94, 106, 165, 236, 404.
Water-vascular ring, 1, 92–94, 165, 405.
Water-vascular system, 92–96, 106, 194, 406.
Water-vessels (radial), 1, 70, 92–94.
Woodocrinus, 20.
Xenocrinus, 42, 44, 181, 183–185, 371, 372.
Zoroaster ackleyi, 399.
fulgens, 106, 395, 399.

EXPLANATION OF THE PLATES.

The following letters are employed throughout all the Plates :—

A. . . Axial cord of the ray or arm.
a. . . Axial cord of a pinnule.
a'. . . Branches of the axial cord in the skeleton.
ac. . . Connective-tissue fibres between the anambulacral plates.
ad. . . The parambulacral extensions of the axial cords into the ventral perisome.
ae. . . Ambulacral epithelium.
ai. . . Primary interradial cords.
an. . . Anambulacral plates.
ar. . . The secondary (radial) cords.
at. . . Anal tube.
B. . . Basal ring.
B_1, B_2. . First and second brachials.
b. . . Radial blood-vessel.
bl. . . Ligaments uniting the basals to the top stem-joint.
br. . . Plug of calcareous tissue in the radial funnel, called a rosette by Sars.
C. . . The body-cavity or coelom.
c. . . The bands of connective-tissue which traverse it.
cd. . . Fibrillar sheath round the vascular axis of the stem.
cd'. . . Its radiating extensions.
cc. . . Coeliac canal.
cco. . . Interradial portion of the circular commissure.
ch. . . Cavities of the chambered organ.
ch'. . . Their downward prolongations into the stem.
chc. . . Fibres of connective tissue which traverse the fibrillar envelope of the chambered organ (central capsule).
chn. . . The nodal enlargements of the peripheral vessels of the stem (*ch'*).
ci. . . Cirrus.
cic. . . Ciliated cups in the coeliac canal.
cp. . . Covering plates.
cs. . . Connective-tissue spaces in the perisome.
cr. . . Cirrus-vessel.
cvc. . . Circumvisceral coelom.
D_1, D_2, D_5, First, second, and fifth distichals.
e. . . External epithelium.
fg. . . Fore-gut.
G. . . Gut.
g. . . Its epithelial lining.
gc. . . Genital cord.
gc'. . . Genital canal.
gv. . . Genital vessel.
ib. . . Intervisceral blood-vessel.
ico. . . Intraradial portion of the circular commissure.
J. . . Arm-joint.
j. . . Pinnule-joint.
l. . . Interradial ligament.
l. . . Basiradial ligament.
lb. . . Interbasal ligament.
ld. . . Dorsal ligament between the arm-joints.
ld'. . . The fossa in which it is lodged.
li. . . Interarticular ligament of the arms.
li'. . . The fossa in which it is lodged.
ln. . . Calcareous network in the perisome.
lp. . . Labial plexus.
lr. . . Its radial extensions beneath the ambulacra.
ls. . . Interarticular ligament of stem.
M. . . Mouth.
m. . . Muscle.
m'. . . Transverse muscle-threads in the water-vessels.
mp. . . Muscle-plate.

a. . . Ambulacral nerve.
nr. . . Its oral ring.
O. . . Oral plate.
ob. . . Oral blood-vascular ring.
ov. . . Ovary.
P. or *p.* . Pigment granules.
pi. . . Pinnule.
R_1, R_2, R_3 First, second, and third radials.
re. . . Rectum.
rm. . . Muscles between the first and second radials.
rm'. . . The fossæ in which they are lodged.
rp. . . Radial plug.
rs. . . Radial space in the stem.
s. . . Spinelets on the disk.
sa. . . Sacculi.
sp. . . Spongy organ.
sp. . . Side plate.
stc. . . Subtentacular canal.
sub. . . Subambulacral plate.
sy. . . Syzygy.
T. . . Tentacle.
t. . . Testis.
tb. . . Tentacular branch of water-vessel.
V. or *v.* . Central vascular axis of stem.
v.r.f. . Ventral radial furrow.
W. or *w.* . Radial water-vessel.
wp. . . Water-pore.
wr. . . Water-vascular ring.
wt. . . Water-tube.
X. or *x.* . Plexiform gland.
xv. . . Its ventral end which joins the labial plexus.

NOTES.

1. In the following lists there is a reference after each figure to a certain page of the Text. In the case of figures which illustrate entire specimens, the reference given is usually to the page in the systematic part of the Report on which the species is first described. But with those figures that represent structural details, reference is given to the page containing the explanation which the figure was designed to illustrate. This is sometimes in the morphological and sometimes in the systematic part of the Report. In a few cases there is no special reference to a figure in the Text; and the number of the page following its explanation is either that of the specific diagnosis; or that of a page containing a description of structural peculiarities which is more or less illustrated by the figure in question.

2. The magnification given for those figures which were drawn before the collection of Stalked Crinoids came into my hands is in most cases only approximate (*circa*). A record was rarely kept of the amount of enlargement; and I have therefore estimated it as closely as possible. All the figures for which I am responsible, however, were drawn according to a definite scale, which varied according to circumstances, but was carefully noted in each case.

3. All the figures which were drawn for Sir Wyville Thomson, and also those on Plates LVII., LIX., and LX. were drawn on the stone in the natural positions of the specimens, so that they appear reversed in the Plates. This should be remembered in future attempts to identify the individuals here described as types; and also in reading the description of the anatomy of the disk in Chapter VI.

ERRATA.

Plate VIIa.—The figure of the radial axillary in the lower right-hand corner *should be* lettered "17" *instead of* "7."

Plate VIIb.—In the upper part of fig. 6, "*a*" *should be* "*a'*," as in the lower part. On the left of fig. 4, "*l*' *should be* "*L*."

Plates XI., XII., XIII., and XVII.—*Instead of* "*Pentacrinus asteria*, L.," *read* "*Pentacrinus asterius*, Linn., sp." (see p. 303).

Plate XXI.—Fig. 1 *should be* "1*a*."

Plate LX.—Fig. 6, "*ad*" *should be* "*a'*."

PLATE I.

PLATE I.

HOLOPUS RANGI, d'Orbigny.

	Diam.	Page
The largest specimen, ...	× 3	199

Fig. 1. The bivial side.

Fig. 2. The trivial side.

1

2

W. H. Rhode Del.

W. & A. K. Johnston, Lith. Edinr.

HOLOPUS RANGII. D'Orbigny.

PLATE II.

PLATE II.

HOLOPUS RANGI, d'Orbigny.

		Diam.	Page
Views of the trivial and bivial sides of an individual which has lost three of the four bivial arms, ...	×	3	199

x 3

J. J. Wild, ad nat. del. M. & N. Hanhart, imp.

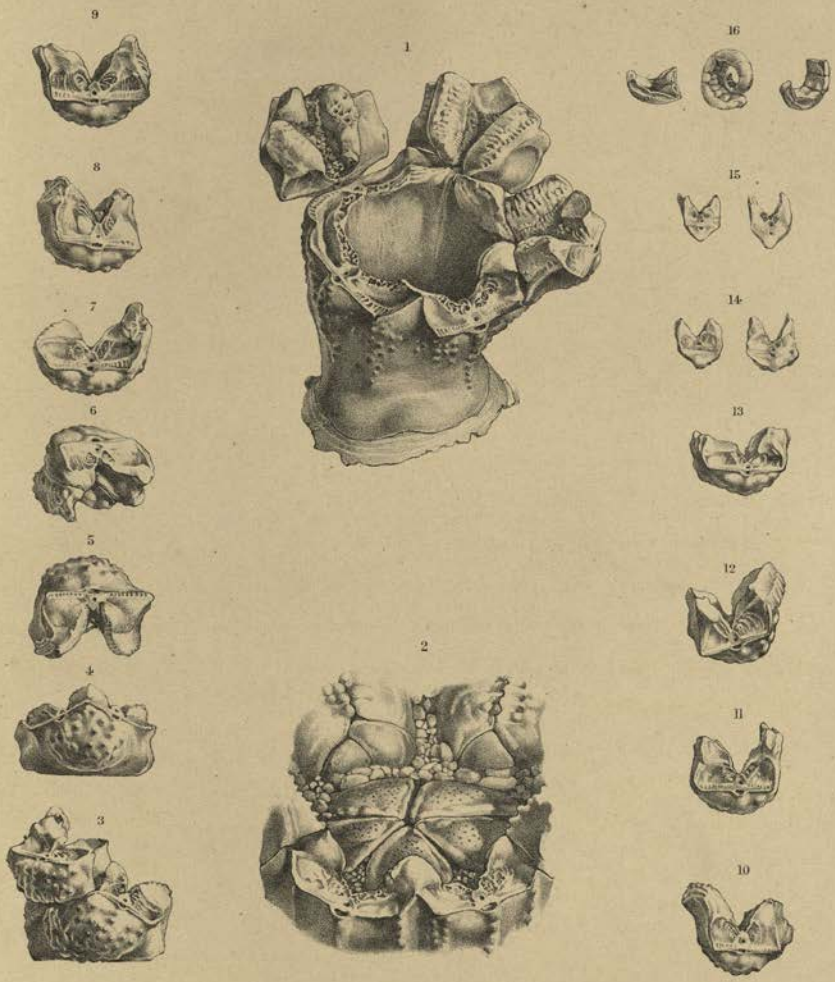
HOLOPUS RANGII, D'Orbigny

PLATE III.

PLATE III.

Holopus rangi, d'Orbigny.

		Diam.	Page
Fig. 1.	View of the cup from above after removal of two of the composite axillaries, ...	× 3	203
Fig. 2.	Interior of the cup of the specimen represented in Pl. II., showing the oral plates. Two axillaries are supposed to be removed, ...	× 5	208
Fig. 3.	Slightly oblique view of the dorsal surfaces of an axillary and the attached first brachial, ...	× 3	206
Fig. 4.	Dorsal aspect of an axillary, ...	× 3	206
Fig. 5.	Oblique view of its proximal face, ...	× 3	206
Fig. 6.	Oblique view of the ventral sides of two united brachials, .	× 3	206
Fig. 7.	Proximal face of the second brachial, ...	× 3	206
Figs. 8–13.	Terminal faces of some of the large lower brachials, .	× 3	207
Figs. 14, 15.	Terminal faces of some of the small outer brachials, .	× 3	207
Fig. 16.	Portions of the pinnules, ...	× 4	208



W. S. Black del.

F. Huth, lith^r Edin^r

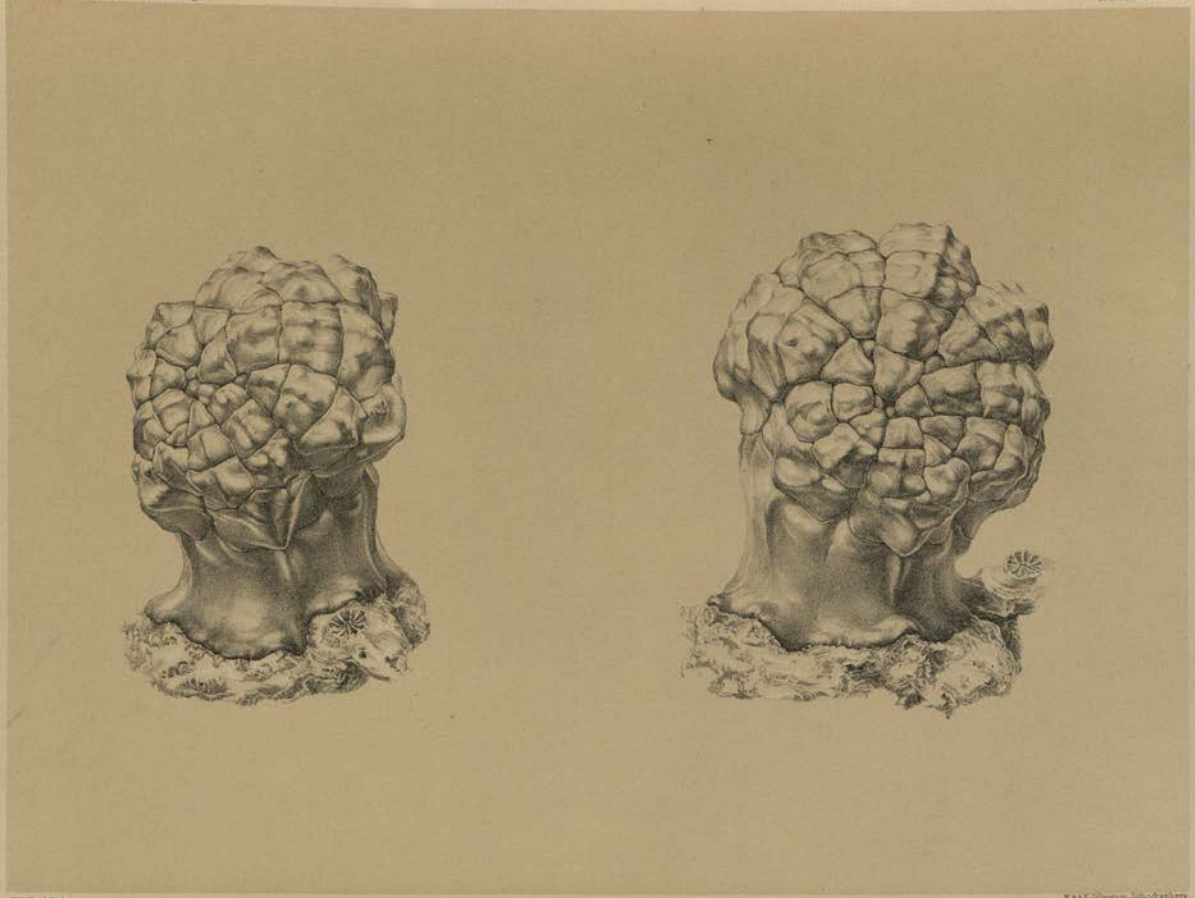
HOLOPUS RANGII, D'Orbigny.

PLATE IV.

PLATE IV.

HOLOPUS RANGI, d'Orbigny.

		Diam.	Page
Side views of a young specimen,	×	10	203



W. H. Black Del.

W. & A. K. Johnston, Lithographers.

HOLOPUS RANGII, D'Orbigny.

PLATE V.

PLATE V.

HOLOPUS RANGI, d'Orbigny.

			Diam.	Page
Fig. 1.	The articular facets of the radials viewed from above, .	×	3	202
Fig. 2.	Horizontal section of the radials, 2 mm. below the edges of the two bivial facets. This is an inferior view of the ring of united radials shown in fig. 1, . . .	×	3	200
Fig. 3.	Vertical section through the lower part of the cup, . .	×	2	201
Fig. 4.	Horizontal section through the lower part of the cup, about 5 mm. above the basal expansion, . . .	×	3	200
Fig. 5.	The calcareous network forming the peripheral portion of the cup, ...	×	45	200
Fig. 6.	The calcareous network forming the inner faces of the radials,	×	45	200
Fig. 7.	Portion of a horizontal section through the cup, showing the relations of the two kinds of network, . . .	×	12	200
Fig. 8.	Ideal representation of the more regular network forming the outside of the cup, ...	×	80	200

Approximately only.

Figs. 9, 10.	The youngest individual dredged by the "Blake,".	×	20	204
	Fig. 9. From the side.			
	Fig. 10. From above.			

Fig 1.

Fig 3.

Fig 2.

Fig 9.

Fig 5.

Fig 6.

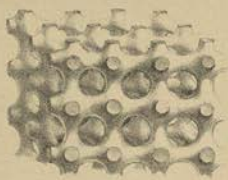


Fig 8.

Fig 10.

Fig 7.

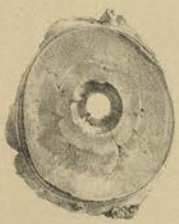


Fig 4.

PLATE Va.

PLATE Va.

HOLOPUS RANGI, d'Orbigny.

		Diam.	Page
Fig. 1.	Ventral aspect of a decalcified arm, showing the ambulacral groove and one of its lateral branches, . . .	× 20	206
Fig. 2.	Side view of a decalcified arm, ...	× 6	208
Fig. 3.	Side view of an entire ray, ...	× 6	208

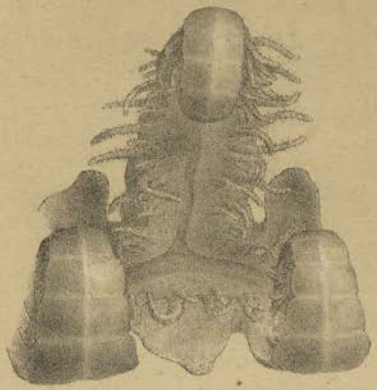


Fig 1.

Fig 2.

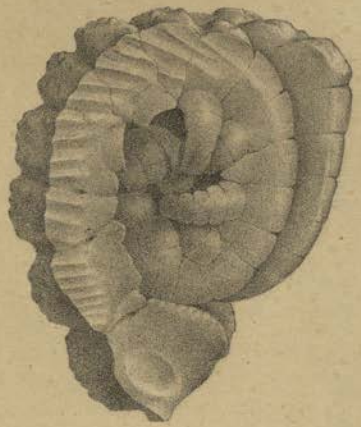


Fig 3.

Geo. West Del. et Lith.

HOLOPUS RANGII, D'ORBIGNY

PLATE Vb.

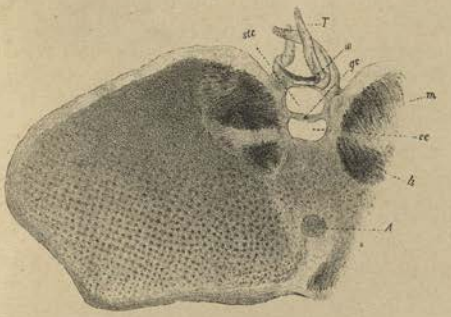
PLATE Vb.

The Lettering is the same in all the Figures.

A. Axial cord.	*m.* Muscle.
cc. Coeliac canal.	*stc.* Subtentacular canal.
gc. Genital cord.	*T.* Tentacle.
j. Pinnule-joint.	*w.* Radial water-vessel.
li. Interarticular ligament.	

HOLOPUS RANGI, d'Orbigny.

		Diam.	Page
Fig. 1. Transverse section of a lower arm-joint, . . .	×	30	209
Fig. 2. The upper portions of three pinnule-joints, showing the armature covering the bases of the tentacles, . . .	×	60	208
Fig. 3. The terminal portion of a pinnule showing the tentacular plates; from a dry specimen, ...	×	40	208
Fig. 4. Inner aspect of an entire ray, showing the rolling in of the distal arm-joints, ...	×	6	206
Fig. 5. Ventral aspect of an axillary and the lower part of an arm, showing the ambulacral groove, ...	×	6	206



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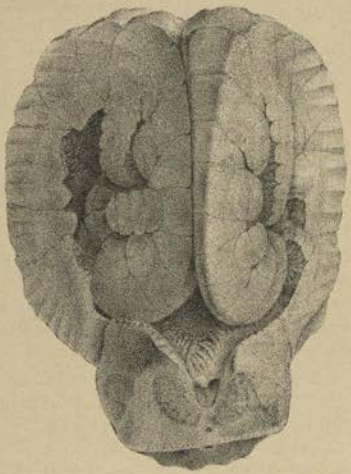
2.



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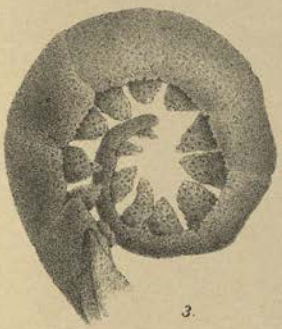


3.

5.

PLATE Vc.

PLATE Vc.

The Lettering is the same in all the Figures.

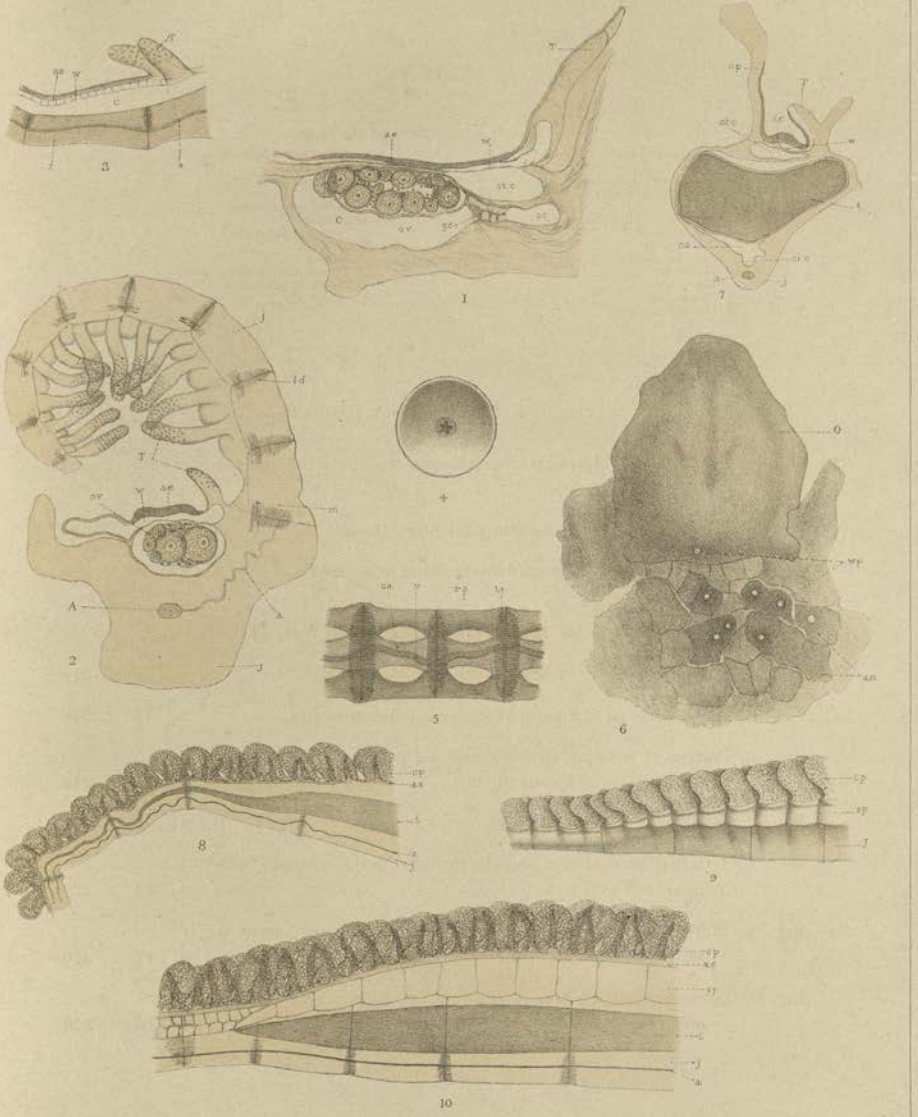
A, Axial cord of arm.
a. Axial cord of pinnule.
ac. Ambulacral epithelium.
am. Anambulacral plate.
C. Coelom.
ca. Fibrillar sheath round vascular axis of stem.
cc. Coeliac canal.
cic. Ciliated cup.
cp. Covering plate.
gc. Genital cord.
J. Arm-joint.
j. Pinnule-joint.
ld. Dorsal ligament.
ls. Interarticular ligament of stem.
m. Muscle.
O. Oral plate.
ov. Ovary.
rs. Radial space in stem.
sp. Side plate.
stc. Subtentacular canal.
T. Tentacle.
t. Testis.
v. Central vascular axis of stem.
w. Radial water-vessel.
wp. Water-pore.

Figs. 1–3. HOLOPUS RANGI, d'Orbigny.

		Diam.	Page
Fig. 1.	Portion of an oblique section through an arm-joint and the base of a pinnule, ... ×	30	210
Fig. 2.	Transverse section of an arm-joint with attached pinnule, . ×	30	210
Fig. 3.	Portion of a nearly longitudinal section of a pinnule, . . ×	35	209

Figs. 4–10. HYOCRINUS BETHELLIANUS, Wyv. Thoms.

Fig. 4.	Terminal face of a stem-joint, ... ×	20	218
Fig. 5.	Optical section of a piece of stem cut longitudinally, . . ×	15	218
Fig. 6.	Portion of the disk, showing one oral plate and the anambulacral plates lying outside it, ... ×	20	219
Fig. 7.	Transverse section of a pinnule, ... ×	80	220
Fig. 8.	Terminal portion of a pinnule, mounted in dammar and seen in optical section, ... ×	15	220
Fig. 9.	Portion of a dry pinnule about the end of the enlargement to receive the genital gland, ... ×	12	220
Fig. 10.	Lower portion of a pinnule, mounted in dammar and seen in optical section, ... ×	16	220



Berjeau & Highley, del. et lith. PH^C dir. Hanhart imp.

1_3 HOLOPUS RANGI, Dorbigny.

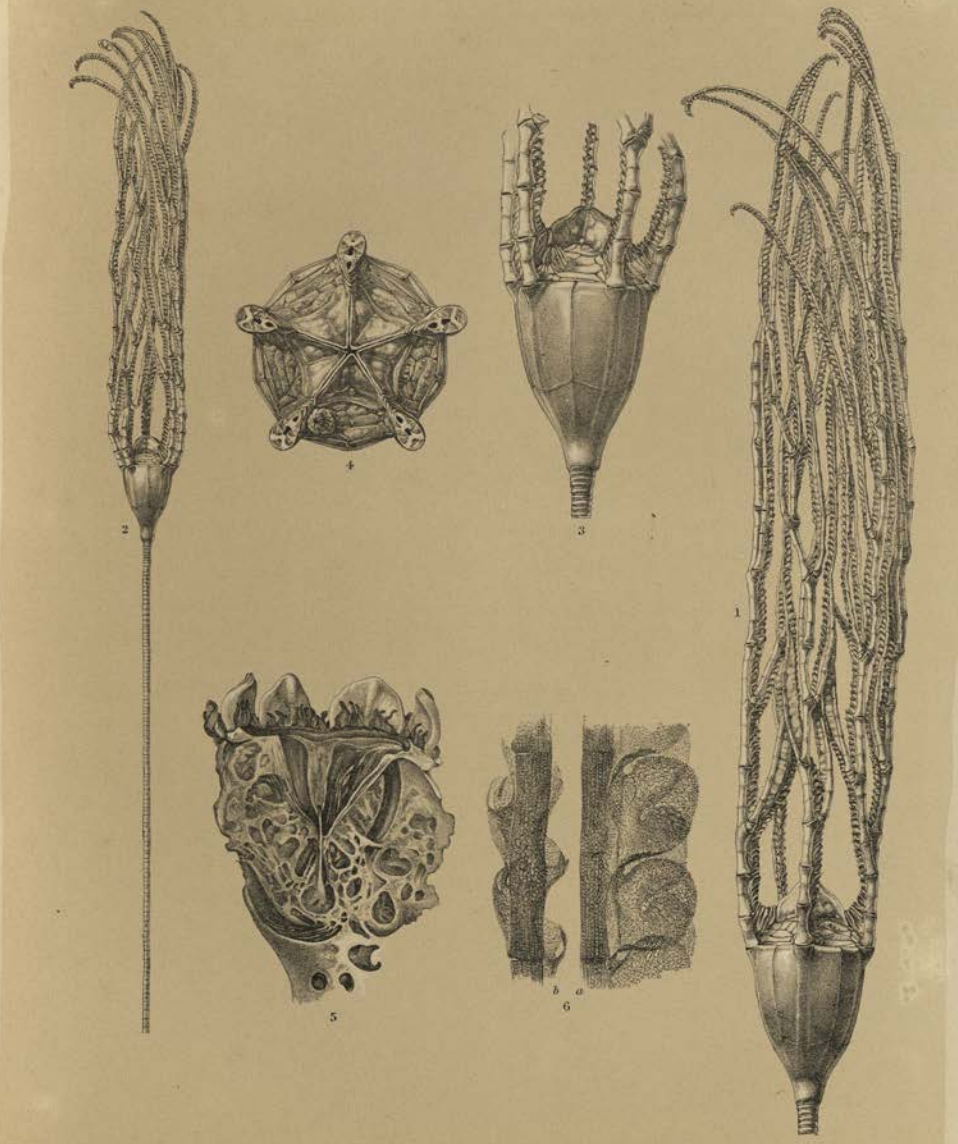
4_10 HYOCRINUS BETHELLIANUS, Sp.n.

PLATE VI.

PLATE VI.

HYOCRINUS BETHELLIANUS, Wyv. Thoms.

			Diam.	Page
Fig. 1.	Radial view of the calyx and arms,	×	4	220
Fig. 2.	Interradial view of the entire specimen,	×	2	218
Fig. 3.	The calyx and arm-bases; anal side,	×	5	218
Fig. 4.	The disk, from above,	×	10	219
Fig. 5.	Inner view of a fragment of the upper portion of the disk,	×	8	220
Fig. 6.	Terminal joints of a pinnule, mounted in dammar,	×	40	220



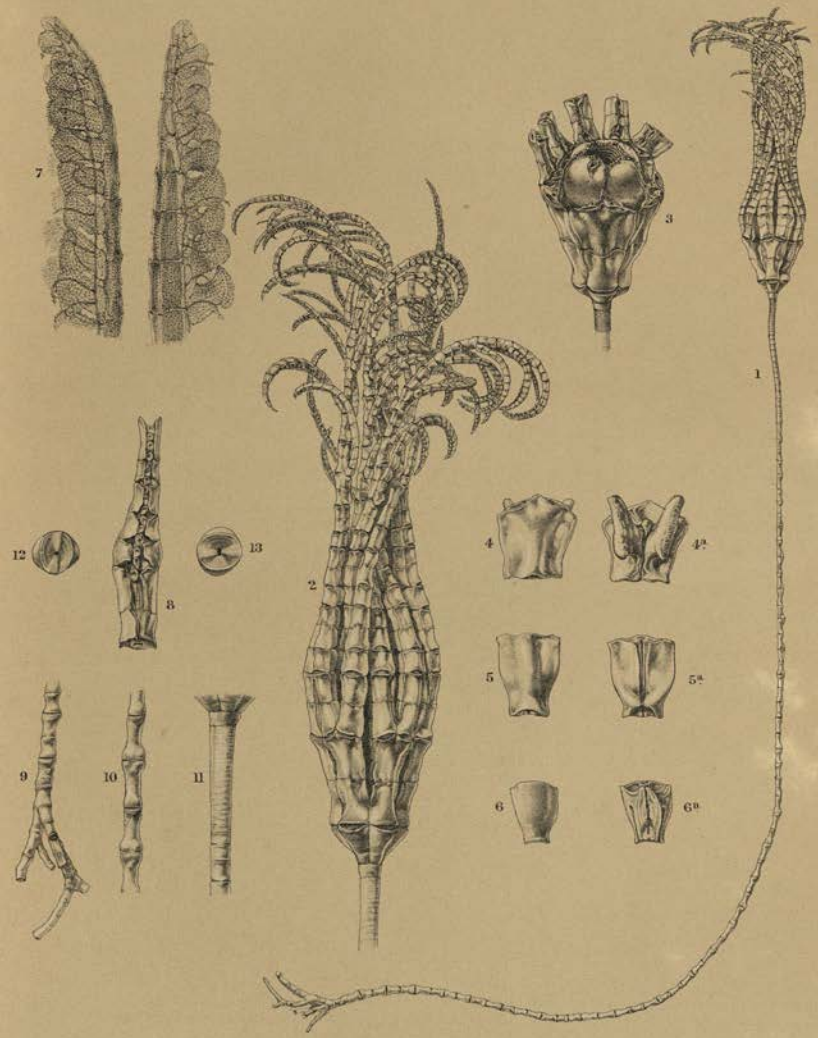
HYOCRINUS BETHELLIANUS, Sp. n.

PLATE VII.

PLATE VII.

BATHYCRINUS ALDRICHIANUS, Wyv. Thoms.

		Diam.		Page
Fig. 1.	An entire specimen, ...	× 1		241
Fig. 2.	The calyx and arms, ...	× 2		241
Fig. 3.	Oblique view of the disk, ...	× 2		234
Figs. 4, 4*a*.	Dorsal and ventral aspects of the radial axillaries, . .	× 6		231
Figs. 5, 5*a*.	Dorsal and ventral aspects of the second radials, .	× 6		231
Figs. 6, 6*a*.	Outer and inner faces of the first radials, . .	× 6		230
Fig. 7.	Terminal portions of two pinnules, mounted in dammar and seen in optical section, ...	× 16		233
Fig. 8.	The lower part of an arm from above, . . .	× 4	Approximate only.	233
Fig. 9.	Lower stem-joints and root, ...	× $2\frac{1}{4}$		28
Fig. 10.	Middle stem-joints, ...	× $2\frac{1}{4}$		27
Fig. 11.	Upper stem-joints and basals, ...	× $2\frac{1}{4}$		226
Figs. 12, 13.	Terminal faces of lower stem-joints, . . .	× 5		27



BATHYCRINUS ALDRICHIANUS, Sp. n.

PLATE VIIa.

PLATE VIIa.

The Lettering is the same in all the Figures.

ca. Fibrillar sheath round vascular axis of stem.
ca'. Its radiating extensions.
ch'. Downward prolongation into the stem of the cavities of the chambered organ.
ld'. Fossa lodging the dorsal ligament.
lt'. Fossa lodging the interarticular ligament.
ls. Interarticular ligament of stem.
p. Pigment bodies.
rm'. Muscular fossæ on the distal face of the first radial.
rs. Radial space in stem.
V. Vascular axis of stem.

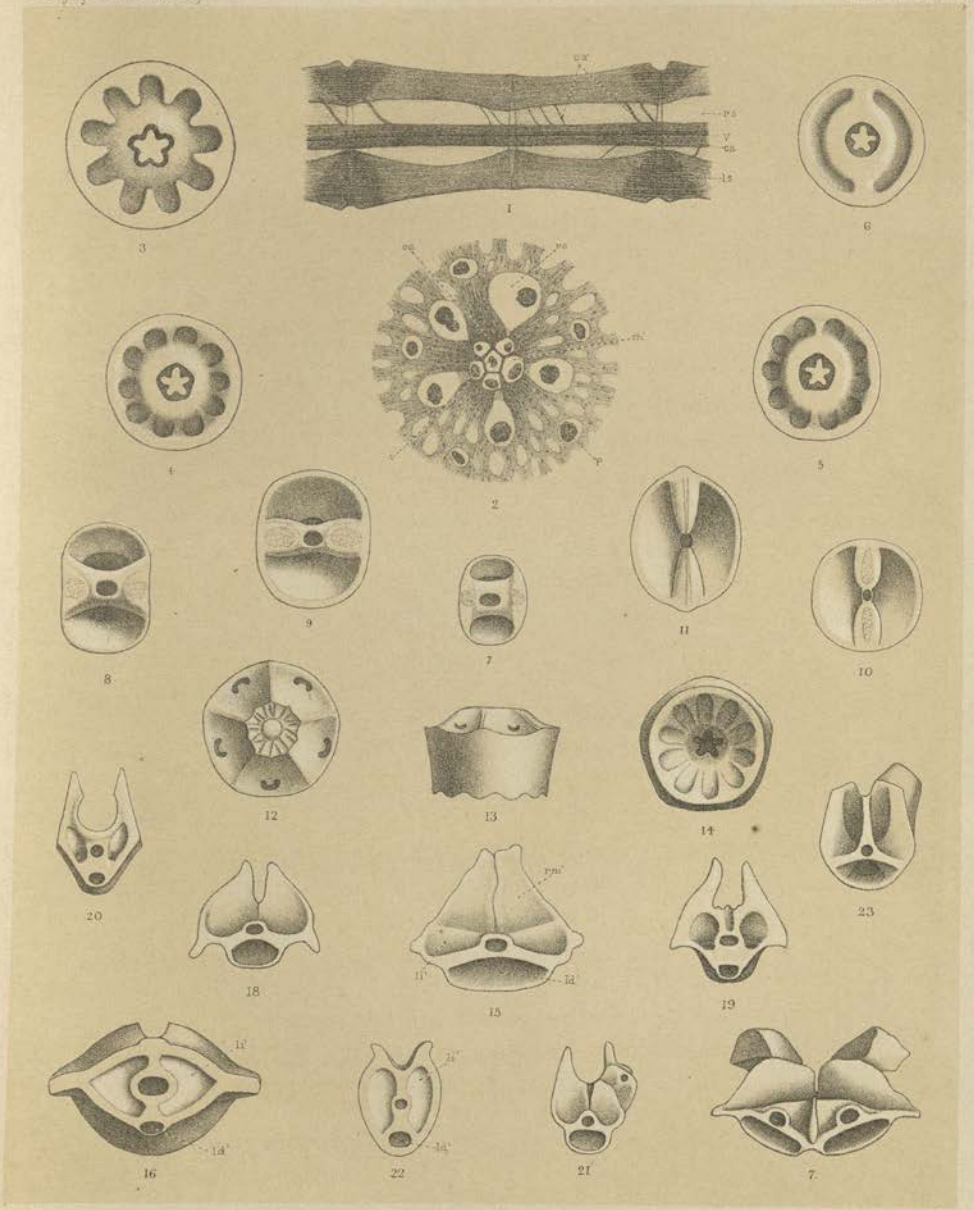
Figs. 1–21. BATHYCRINUS ALDRICHIANUS, Wyv. Thoms.

			Diam.	Page
Fig. 1.	Optical section of a piece of stem, cut longitudinally, . .	×	66	31
Fig. 2.	Transverse section of stem, central portion, . . .	×	300	31
Fig. 3.	Upper face of top stem-joint, ...	×	26	26
Fig. 4.	Upper face of third joint, ...	×	26	26
Fig. 5.	Upper face of fifth joint, ...	×	26	27
Fig. 6.	Upper face of ninth joint, ...	×	26	27
Fig. 7.	Upper stem-joint, ...	×	16	27
Figs. 8, 9.	Middle stem-joints, ...	×	16	27
Figs. 10, 11.	Lower stem-joints, ...	×	16	27
Figs. 12–14.	The basal ring, ...	×	17	226
	Fig. 12. From above.			
	Fig. 13. From the side.			
	Fig. 14. From below.			
Fig. 15.	Distal face of first radial, ...	×	16	231
Fig. 16.	Distal face of second radial, ...	×	16	231
Fig. 17.[1]	Distal aspect of axillary, ...	×	16	231
Figs. 18, 19.	Distal and proximal faces of the fifth brachial, . .	×	16	232
Figs. 20, 21.	Proximal and distal faces of an outer brachial, . .	×	16	232

Figs. 22, 23. BATHYCRINUS CAMPBELLIANUS, n. sp.

Figs. 22, 23.	Proximal and distal faces of an outer brachial, . .	×	30	232

[1] This figure is wrongly lettered 7 on the plate.



Benjeau & Highley del et lith. PRC. dir. Hanhart imp.

BATHYCRINUS ALDRICHIANUS, Sp.n.
" " CAMPBELLIANUS, Sp.n.

PLATE VIIb.

PLATE VIIb.

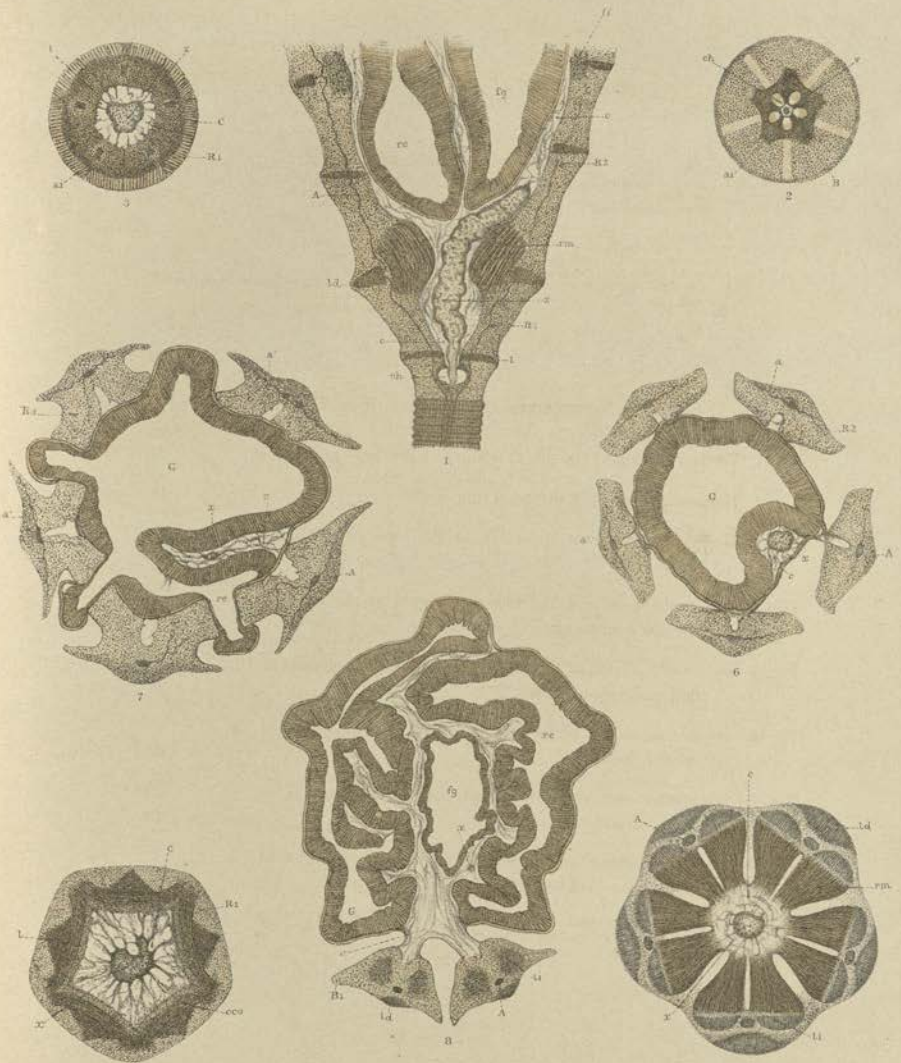
The Lettering is the same in all the Figures.

A. Axial cord of ray or arm.
a'. Its branches.
ai. Primary interradial cords.
B. Basal ring.
B_1. First brachials.
C. Coelom or body-cavity.
c. Network of connective tissue within the coelom.
eco. Interradial portion of the circular commissure.
ch. Cavities of the chambered organ.
fg. Fore-gut.
G. Gut.
L. Interradial ligament.
l. Basiradial ligament.
ld. Dorsal ligament.
li. Interarticular ligament.
R_1. First radials.
R_2. Second radials.
R_3. Third radials.
re. Rectum.
rm. Muscles uniting the first and second radials.
V. Vascular axis of stem.
x. Plexiform gland.

BATHYCRINUS ALDRICHIANUS, Wyv. Thoms.

		Diam.	Page
Fig. 1. Vertical section of the calyx, with the lower part of the disk, .	×	20	235
Fig. 2. Horizontal section of the basal ring, ...	×	45	226
Fig. 3. Horizontal section of the calyx at the level of the basiradial suture, ...	×	45	228
Fig. 4. Horizontal section of the radial pentagon at the level of the circular commissure, ...	×	20	230
Fig. 5. Horizontal section of the calyx, through the articulation of the first and second radials, ...	×	20	230
Fig. 6.[1] Horizontal section of the calyx, through the upper part of the second radials, ...	×	20	231
Fig. 7.[2] Horizontal section of the calyx, through the middle of the third radials, ...	×	22	231
Fig. 8. Horizontal section of the disk, through the articulation of the first and second brachials, ...	×	20	232

[1] In the upper part of this figure *a* should be *a'*, as in the lower part.
[2] On the left of this figure *l* should be *L*.



Berjeau & Highley del.et lith. P.H.C. dir. Hanhart imp.

BATHYCRINUS ALDRICHIANUS, Sp.n.

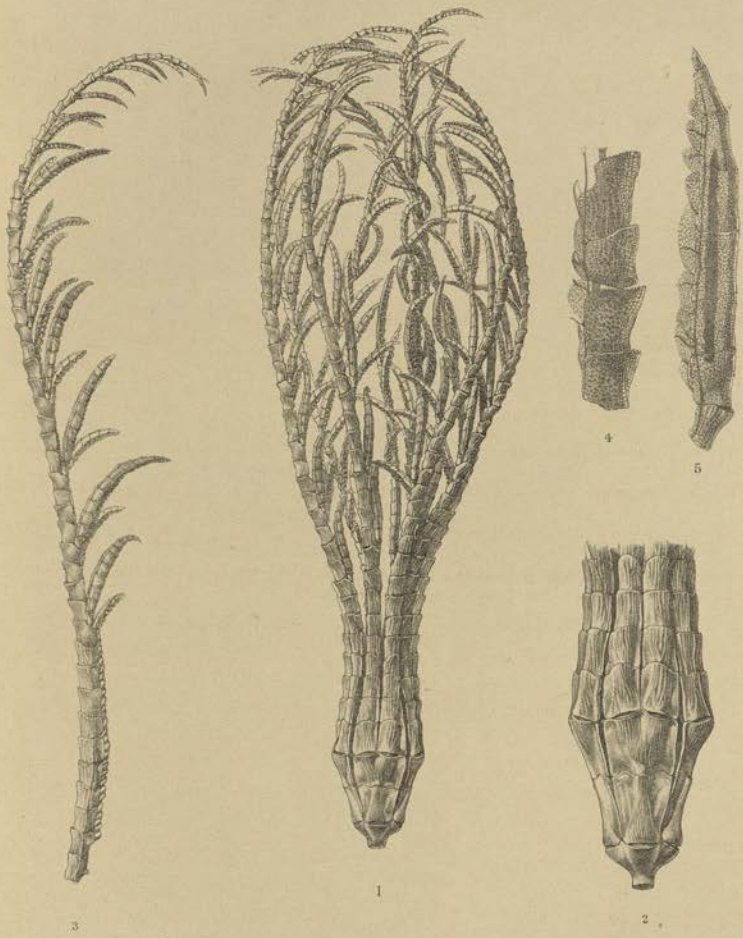
PLATE VIII.

PLATE VIII.

BATHYCRINUS CAMPBELLIANUS, n. sp.

		Diam.	Page
Fig. 1. Calyx and arms separated from the stem and basal ring, .	×	3	238
Fig. 2. The radials and arm-bases, ...	×	8	238
Fig. 3. Side view of one arm, ...	×	6	234
Fig. 4. Four of the lower arm-joints, from the side, . . .	×	16	238
Fig. 5. Side view of a pinnule, mounted in dammar, . . .	×	20	233

N.B.—The magnification given above is only approximate, as it was not recorded at the time the Plate was drawn, though I have endeavoured to work it out subsequently.



W. S. Black, del.

F. Huth, Lith^r Edin^r

BATHYCRINUS CAMPBELLIANUS, Sp. n.

PLATE VIIIa.

PLATE VIIIa.

The Lettering is the same in all the Figures.

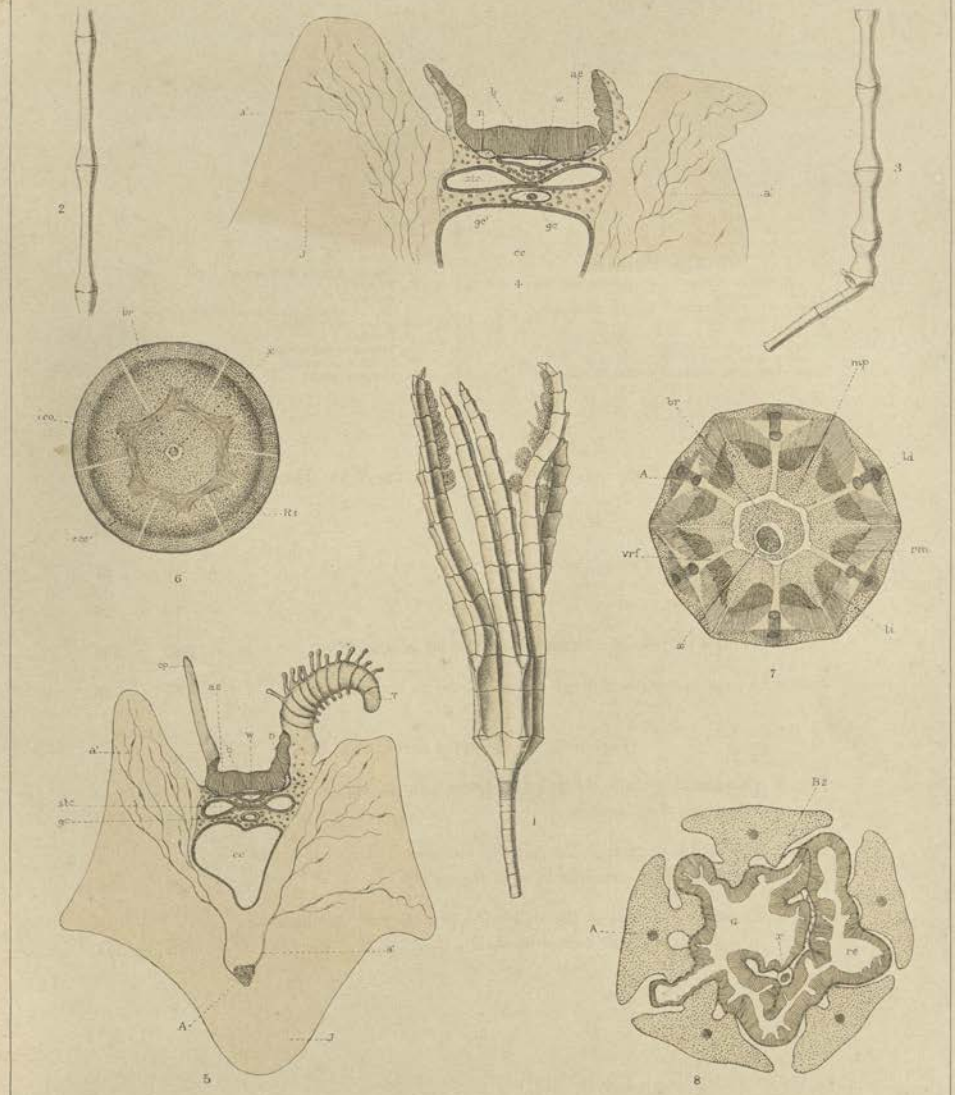
A. Axial cord of arm.
a'. Its branches.
ae. Ambulacral epithelium.
B_2. Second brachial.
b. Radial blood-vessel.
br. Ring of calcareous tissue, called a basal rosette by Sars.
cc. Coeliac canal.
cco. Interradial portion of circular commissure.
cp. Covering plate.
G. Gut.
gc. Genital cord.
gc'. Genital canal.
ico. Intraradial portion of circular commissure.
J. Arm-joint.
ld. Dorsal ligament.
li. Interarticular ligament.
mp. Muscle-plate.
n. Ventral or ambulacral nerve.
R_1. First radial.
re. Rectum.
rm. Muscles uniting the first and second radials.
stc. Subtentacular canal.
T. Tentacle.
vrf. Ventral radial furrow.
W. Radial water-vessel.
x. Plexiform gland.

Figs. 1–3. BATHYCRINUS GRACILIS, Wyv. Thoms.

		Diam.	Page
Fig. 1. Head and upper part of stem,	×	10	243
Fig. 2. Middle part of stem,	×	10	27
Fig. 3. Lowest part of stem,	×	10	27
Fig. 4. Ventral portion of a transverse section of an arm,	×	285	236
Fig. 5. An entire section through the middle of an arm-joint,	×	165	236

Figs. 6–8. RHIZOCRINUS LOFOTENSIS, Sars.

Fig. 6. Horizontal section through the lower part of the radials, of which there are six,	×	35	250
Fig. 7. Horizontal section of the calyx of the same individual at the level of the articular faces of the radials,	×	35	252
Fig. 8. Horizontal section of the disk of a pentamerous specimen at the level of the second brachials,	×	40	254



Berjeau & Highley. del et lith. P.H.C. dir. Hanhart imp.

1-3. BATHYCRINUS GRACILIS, Wy. Th.
4, 5. BATHYCRINUS ALDRICHIANUS, Sp. n.
6-8. RHIZOCRINUS LOFOTENSIS, Sars.

PLATE IX.

PLATE IX.

Figs. 1, 2. RHIZOCRINUS LOFOTENSIS, Sars.

		Diam.	Page
Fig. 1. An entire specimen, ...	×	3	259
Fig. 2. The calyx and arms, ...	×	6	259

Figs. 3–5. RHIZOCRINUS RAWSONI, Pourtalès.

Fig. 3. General view of an entire specimen with the exception of the lowest part of the stem,[1]	×	2	262
Fig. 4. Portion of an arm, from the side, ...	×	12	60
Fig. 5. Dorsal aspect of an arm, ...	×	12	60

N.B.—The magnification is only approximate, as in Pl. VIII.

[1] This figure was drawn from a dry specimen, parts of which had shown a tendency to separate; and the gaps had consequently been filled up with gum. In consequence of this the syzygy between the first two brachials of the middle ray was wrongly drawn as a muscular joint like that between the second and third brachials. It should have been represented as a simple line without any gap between the joints, like the syzygies in the remaining part of the arm.

RHIZOCRINUS LOFOTENSIS, M. Sars.
" " RAWSONI, POURTALES.

PLATE X

PLATE X.

The same Letters occur in both Figures.

br. The plug of calcareous tissue in the centre of the radial funnel, which was called a basal rosette by Sars.
vrf. The ventral radial furrows of the calyx.

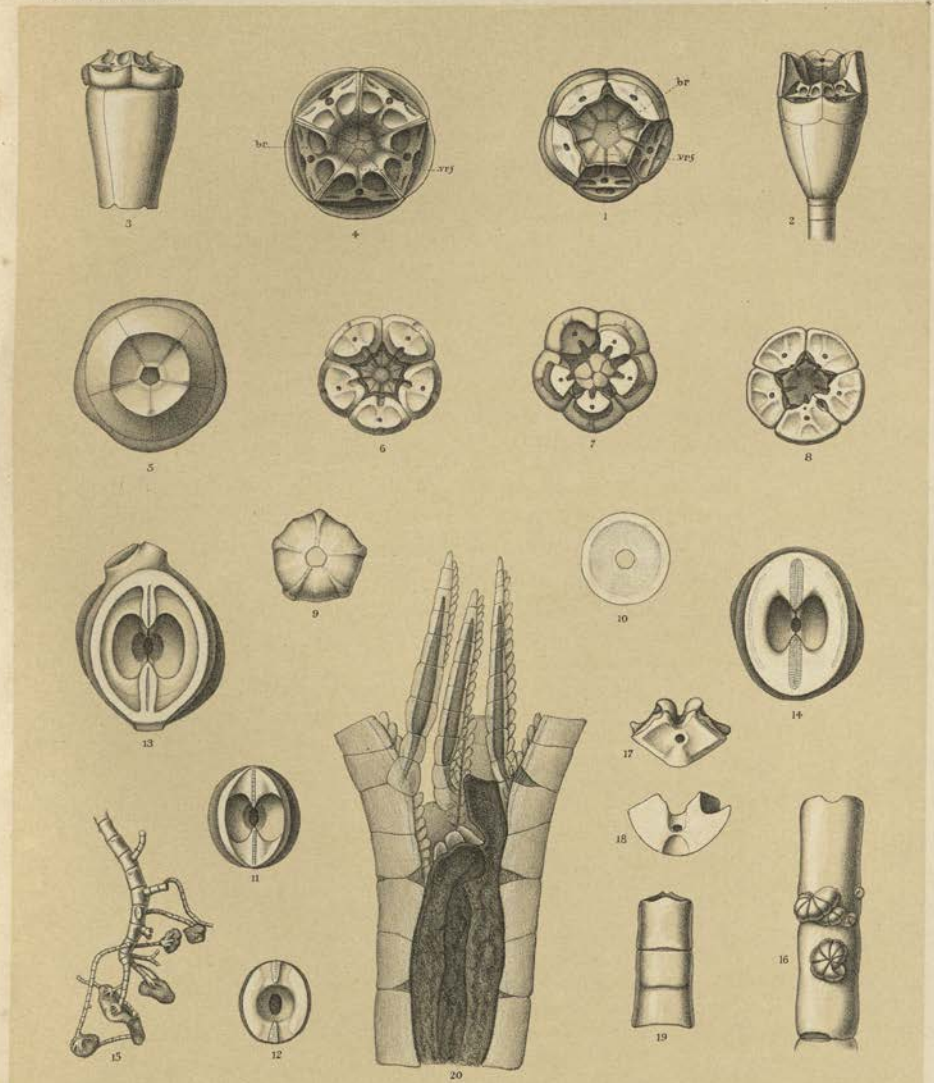
Figs. 1, 2. RHIZOCRINUS LOFOTENSIS, Sars.

Two views of a calyx with three of the first brachials remaining *in situ*.

			Diam.	Page
Fig. 1.	From above,	×	15	252
Fig. 2.	From the side,	×	10	266

Figs. 3–20. RHIZOCRINUS RAWSONI, Pourtalès.

			Diam.	Page
Fig. 3.	Calyx of a specimen from near the Azores; side view,	×	10	267
Fig. 4.	The same from above,	×	15	250
Fig. 5.	The same from below,	×	15	25
Fig. 6.	Calyx of a specimen from off Havana, with the first brachials remaining *in situ*; from above,	×	10	254
Fig. 7.	A similar view of the calyx of another Havana specimen which has undergone reparation. All the first brachials are visible and four of the small second brachials; while the centre of the cup is occupied by the oral plates,	×	10	255
Fig. 8.	Calyx of another specimen from the Azores with the first brachials attached; from above,	×	10	255
Fig. 9.	Upper face of the top stem-joint of the Azores specimen represented in figs. 3–5,	×	15	25
Fig. 10.	Upper face of the fourth joint of the same stem,	×	15	25
Figs. 11, 12.	Terminal faces of two joints from rather above the middle of the stem; fig. 12 representing that nearer the calyx,	×	15	26
Figs. 13, 14.	Terminal faces of two joints from the lower part of the stem; fig. 13 representing that nearer the root,	×	15	26
Fig. 15.	The root of a specimen from Havana,	×	1½	257
Fig. 16.	Two stem-joints with attached Foraminifera (*Truncatulina lobatula*),	×	10	134
Fig. 17.	Proximal face of an epizygal at an arm-syzygy,	×	15	254
Fig. 18.	Distal face of the corresponding hypozygal,	×	15	254
Fig. 19.	Dorsal view of the second and two following brachials, to show the backward projection of the proximal face of the second brachial (an epizygal),	×	10	254
Fig. 20.	Side view of the upper part of the disk, after removal of one arm. The arms have separated from the cup at the syzygy between the first and second brachials,	×	15	255



Berjeau & Highley del.et lith. PHC dir. Hanhart imp.

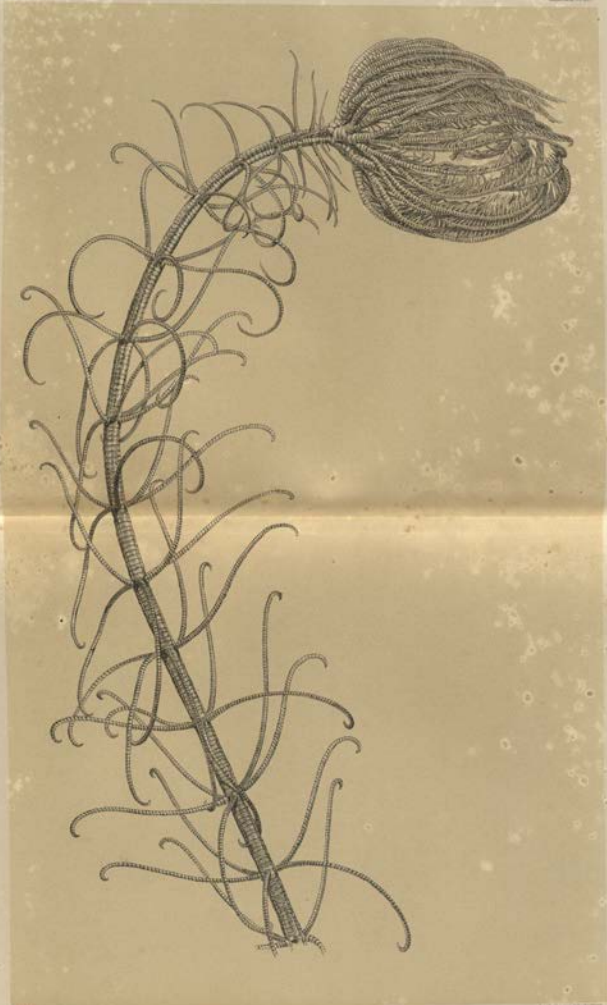
1,2 RHIZOCRINUS LOFOTENSIS, Sars.
3-20 „ RAWSONI, Pourt.

PLATE XI.

PLATE XI.

PENTACRINUS ASTERIUS, Linn., sp.

Natural size, p. 300.



PENTACRINUS ASTERIA. L.

PLATE XII.

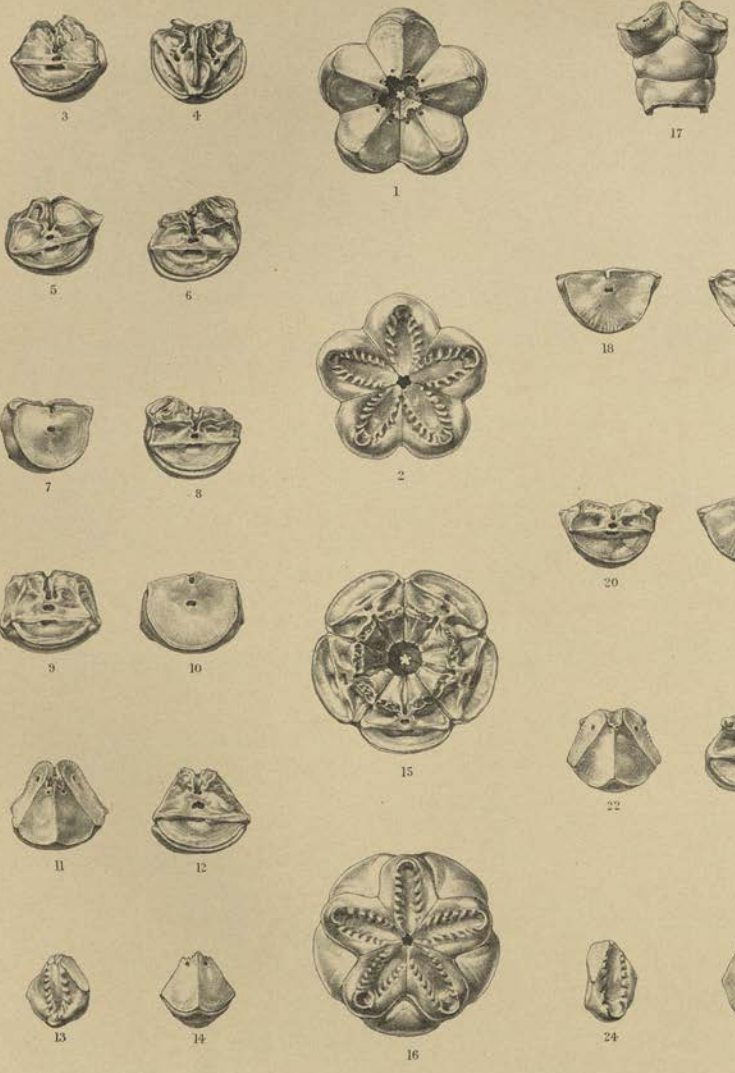
PLATE XII.

Figs. 1–14. METACRINUS ANGULATUS, n. sp.

		Diam.	Page
Figs. 1, 2. Upper and lower views of the basal ring,	×	3	291
Figs. 3, 4. Proximal and distal faces of the fourth (axillary) radial,	×	3	9
Figs. 5, 6. Proximal and distal faces of the third radial,	×	3	48
Figs. 7, 8. Proximal and distal faces of the epizygal of the second radial,	×	3	48
Figs. 9, 10. Proximal and distal faces of the hypozygal of the second radial,	×	3	9
Fig. 11. Lower or dorsal aspect of a first radial,	×	3	293
Fig. 12. Distal articular face of a first radial,	×	3	9
Figs. 13, 14. An isolated basal, from below and above,	×	3	293

Figs. 15–25. PENTACRINUS ASTERIUS, Linn., sp.

Figs 15, 16. Upper and lower views of the calyx,	×	3	33
Fig. 17. Dorsal aspect of the two outer radials with the first distichals attached,	×	3	300
Figs. 18, 19. Proximal and distal faces of the third (axillary) radials,	×	3	305
Figs. 20, 21. Proximal and distal faces of the second radials,	×	3	305
Fig. 22. Lower or dorsal aspect of a first radial,	×	3	293
Fig. 23. Distal articular face of a first radial,	×	3	9
Figs. 24, 25. An isolated basal, from below and above,	×	3	293



W.S. Black, del. J. Bell, Lith^r Edin^r

1–14. METACRINUS ANGULATUS, Sp. n.
15–25. PENTACRINUS ASTERIA, L.

PLATE XIII.

PLATE XIII.

PENTACRINUS ASTERIUS, Linn., sp.

			Diam.	Page
Fig. 1.	The calyx and arm-bases,	×	2	300
	Figs. 2–4. A nodal joint from the upper part of the stem.			
Fig. 2.	Upper face,	×	5	17
Fig. 3.	Lower face,	×	5	17
Fig. 4.	Side view,	×	5	14
Fig. 5.	A nodal joint from the lower part of the stem; lower face,	×	4	17
Fig. 6.	The same; upper face,	×	4	17
Fig. 7.	Portion of an internode from near the top of the stem,	×	2	18
Fig. 8.	Nodal and internodal joints from the lower part of the stem,	×	2	305
Fig. 9.	Face of a young internodal joint,	×	5	15
Figs. 10, 11.	Faces of older internodal joints,	×	4	17
Fig. 12.	Terminal face of a pinnule-joint,	×	5	10
Fig. 13.	Termination of an arm,	×	2	300
Fig. 14.	One of the middle arm-joints and its pinnule,	×	4	286
Fig. 15.	The ambulacral skeleton of an outer pinnule,	×	30	79
Fig. 16.	Ventral aspect of the basal joints of a lower pinnule, showing the development of its ambulacral skeleton,	×	10	79

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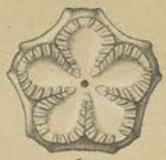
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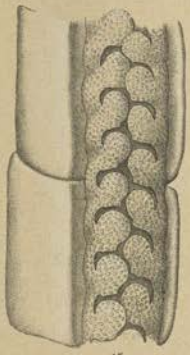
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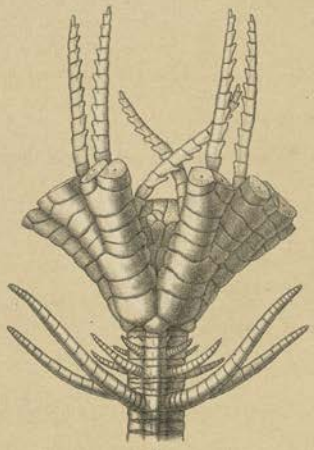
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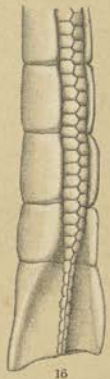
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Berjeau & Highley del. et lith. P.H.C. dir. Hanhart imp.

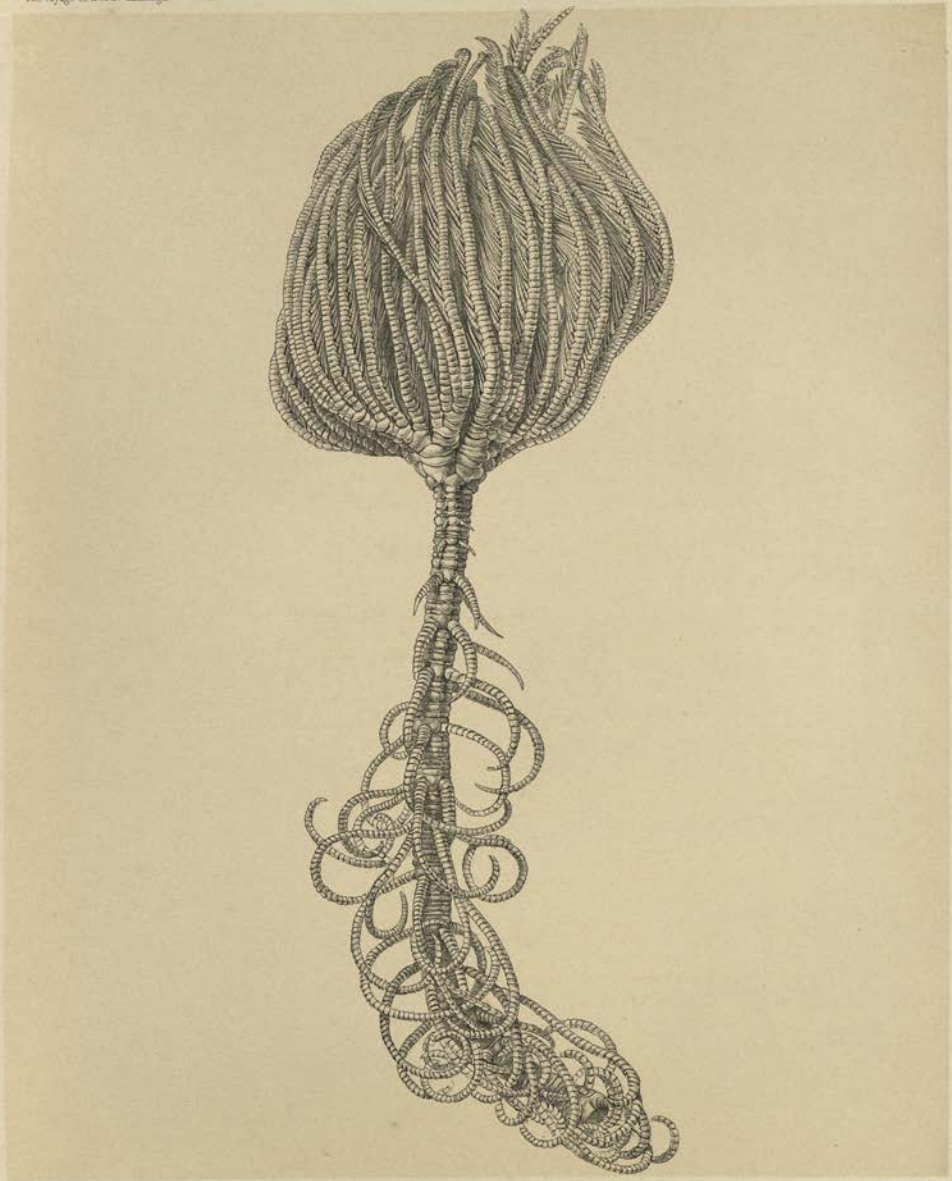
PENTACRINUS ASTERIA, Linn.

PLATE XIV.

PLATE XIV.

PENTACRINUS MÜLLERI, Oersted.

Natural size, p. 306.



W. S. Kirk, del.

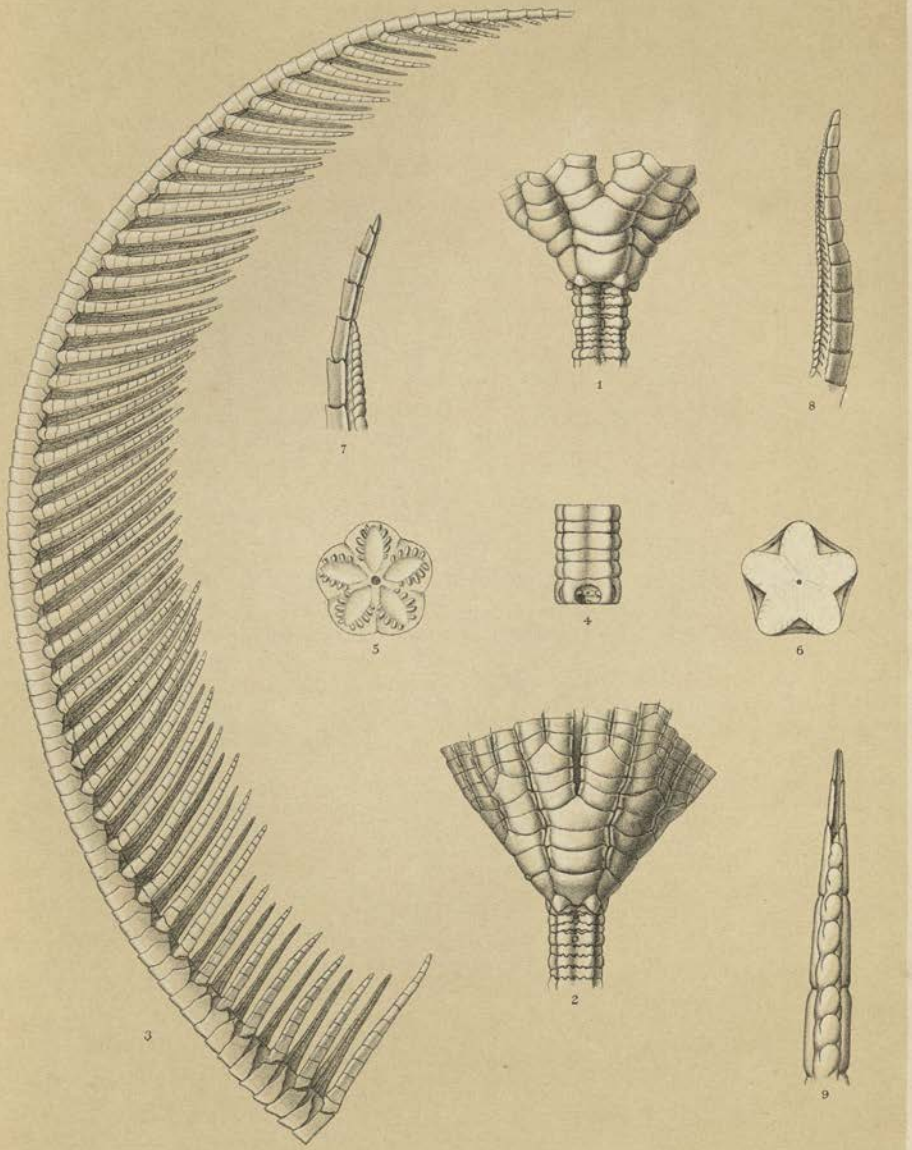
PENTACRINUS MÜLLERI, Oersted.

PLATE XV.

PLATE XV.

PENTACRINUS MÜLLERI, Oersted.

		Diam.	Page
Fig. 1. The calyx and arm-bases, . . .	×	2	311
Fig. 2. Another specimen with four radials, ...	×	2	311
Fig. 3. An arm of this specimen (Martinique), . . .	×	2	311
Fig. 4. Portion of the stem, ...	×	2	310
Fig. 5. Face of an internodal joint, ...	×	4	12
Fig. 6. Lower or syzygial face of a nodal joint, . . .	×	4	17
Figs. 7, 8. The ends of two pinnules, showing the termination of the ambulacral skeleton; from the side, . . .	×	15	80
Fig. 9. The same; from above, ...	×	20	312



Berjeau & Highley del.et lith. P.H.C. dir. Hanhart imp.

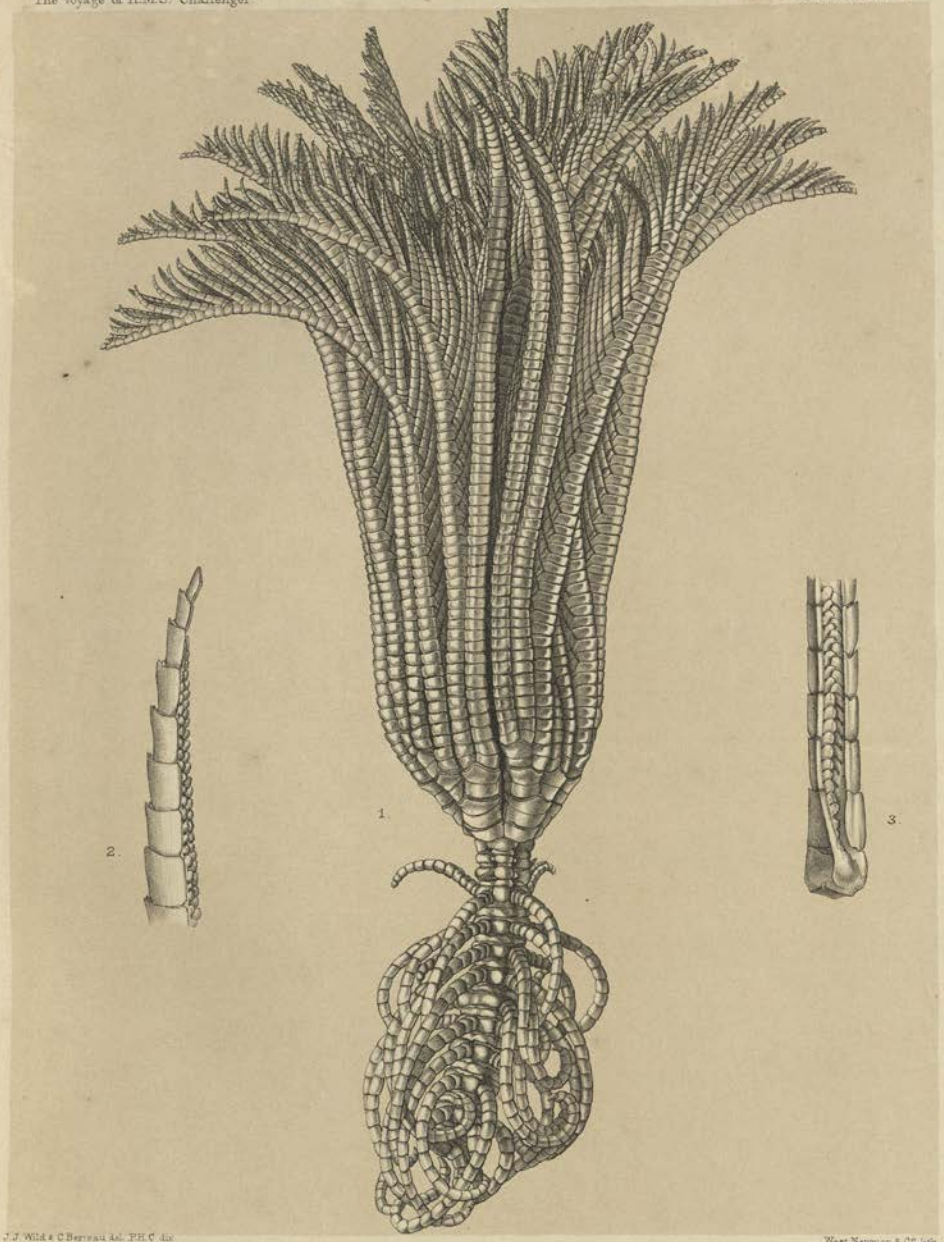
PENTACRINUS MÜLLERI, Oersted.

PLATE XVI.

PLATE XVI.

PENTACRINUS MACLEARANUS, Wyv. Thoms.

			Diam.	Page
Fig. 1.	The entire specimen, ...	×	2	312
Fig. 2.	The end of a pinnule; from the side, ...	×	12	55
Fig. 3.	Ventral aspect of the basal joints of a pinnule, showing the development of its ambulacral skeleton, ...	×	12	80



J. J. Wild & C. Beryeau del. P.H.C. dir.

West Newman & Co. lith.

PENTACRINUS MACLEARANUS, sp. n.

PLATE XVII.

PLATE XVII.

Fig. 1. PENTACRINUS MACLEARANUS, Wyv. Thoms.

			Diam.	Page
Fig. 1.	Arm-groove of *Pentacrinus macleararanus*, . . .	×	8	80

Figs. 2–6. PENTACRINUS WYVILLE-THOMSONI, Jeffreys.

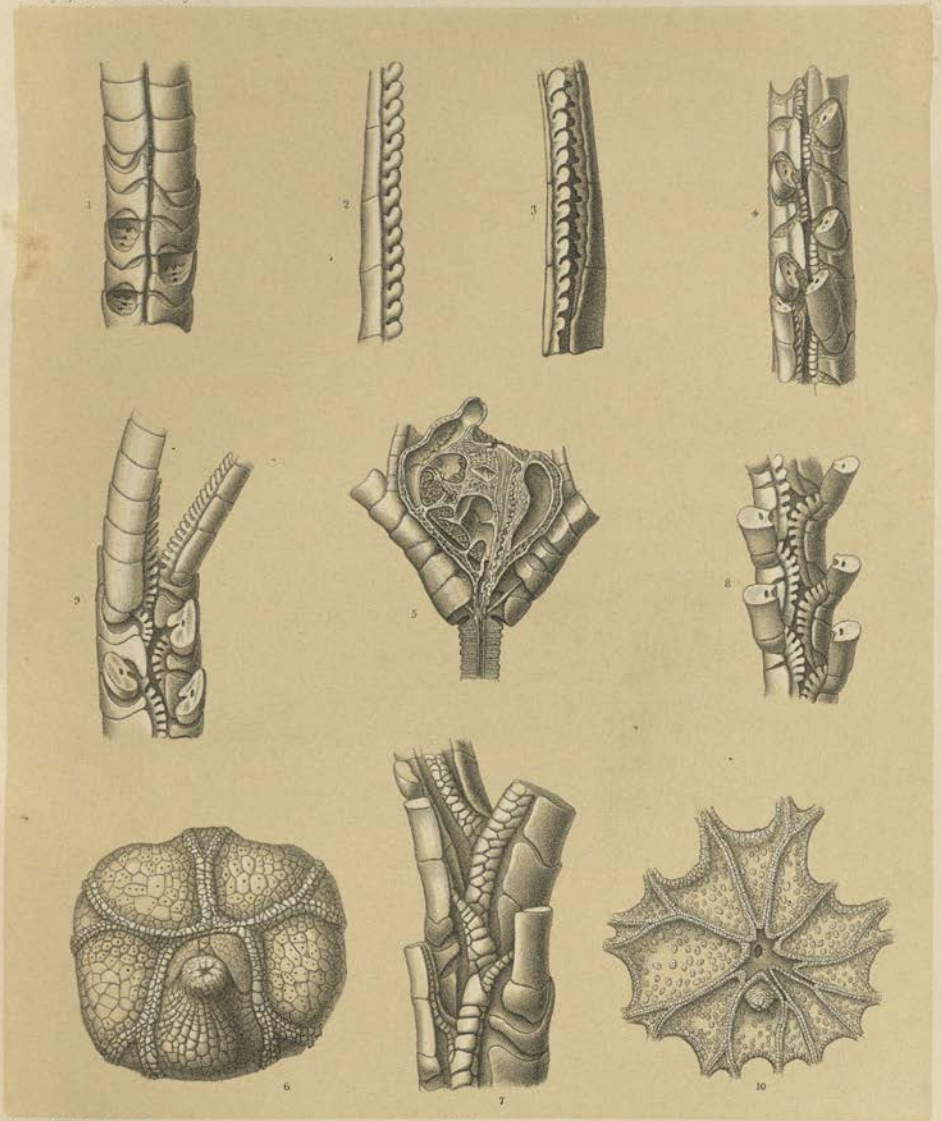
Fig. 2.	Ambulacral skeleton of a pinnule; from the side, . .	×	12	320
Fig. 3.	The same, near the base of the pinnule; from above, .	×	12	320
Fig. 4.	The arm-groove and brachial ambulacrum, . . .	×	8	320
Fig. 5.	Vertical section of a decalcified specimen. Much of the alimentary epithelium has fallen away. The lobulated organ to the right of the centre of the figure is the plexiform gland,	×	3	33
Fig. 6.	The disk of a dry specimen, ...	×	6	320

Figs. 7, 8. PENTACRINUS ASTERIUS, Linn, sp.

Fig. 7.	Ventral aspect of one of the lower arm-divisions, showing the ambulacral skeleton, ...	×	8	79
Fig. 8.	The arm-groove and brachial ambulacrum, . . .	×	8	79

Figs. 9, 10. PENTACRINUS MÜLLERI, Oersted.

Fig. 9.	The arm-groove and brachial ambulacrum, . . .	×	8	80
Fig. 10.	The disk of a spirit-specimen, ...	×	3	311



Berjeau & Highley, del. et lith. P.H.C. Dir. Hanhart, imp.

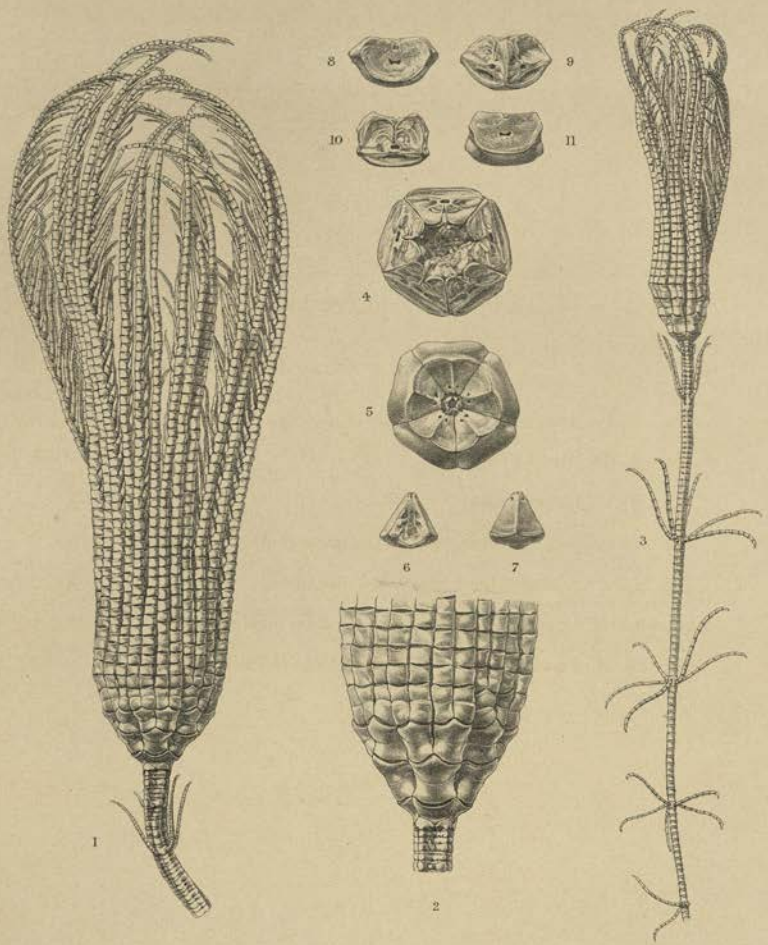
1 PENTACRINUS MACLEARANUS, Sp.n. 2-6 P. WYVILLE THOMSONI, Jeffreys.
7,8. P. ASTERIA, L. 9,10. P. MÜLLERI, Oersted.

PLATE XVIII.

PLATE XVIII.

PENTACRINUS WYVILLE-THOMSONI, Jeffreys.

			Diam.	Page
Fig. 1.	The head, with the upper part of the stem, . . .	×	1½	313
Fig. 2.	The calyx and arm-bases, ...	×	2	320
Fig. 3.	A young specimen, ...	×	2	21
Figs. 4, 5.	Upper and lower views of the radial pentagon, . .	×	3	33
Figs. 6, 7.	An isolated basal from below and above, . . .	×	3	293
Figs. 8, 9.	Proximal and distal faces of the third (axillary) radial, .	×	3	50
Figs. 10, 11.	Proximal and distal faces of the second radial, . .	×	3	50



W. S. Blanc, del. F. Huth, Lith^r Edin^r

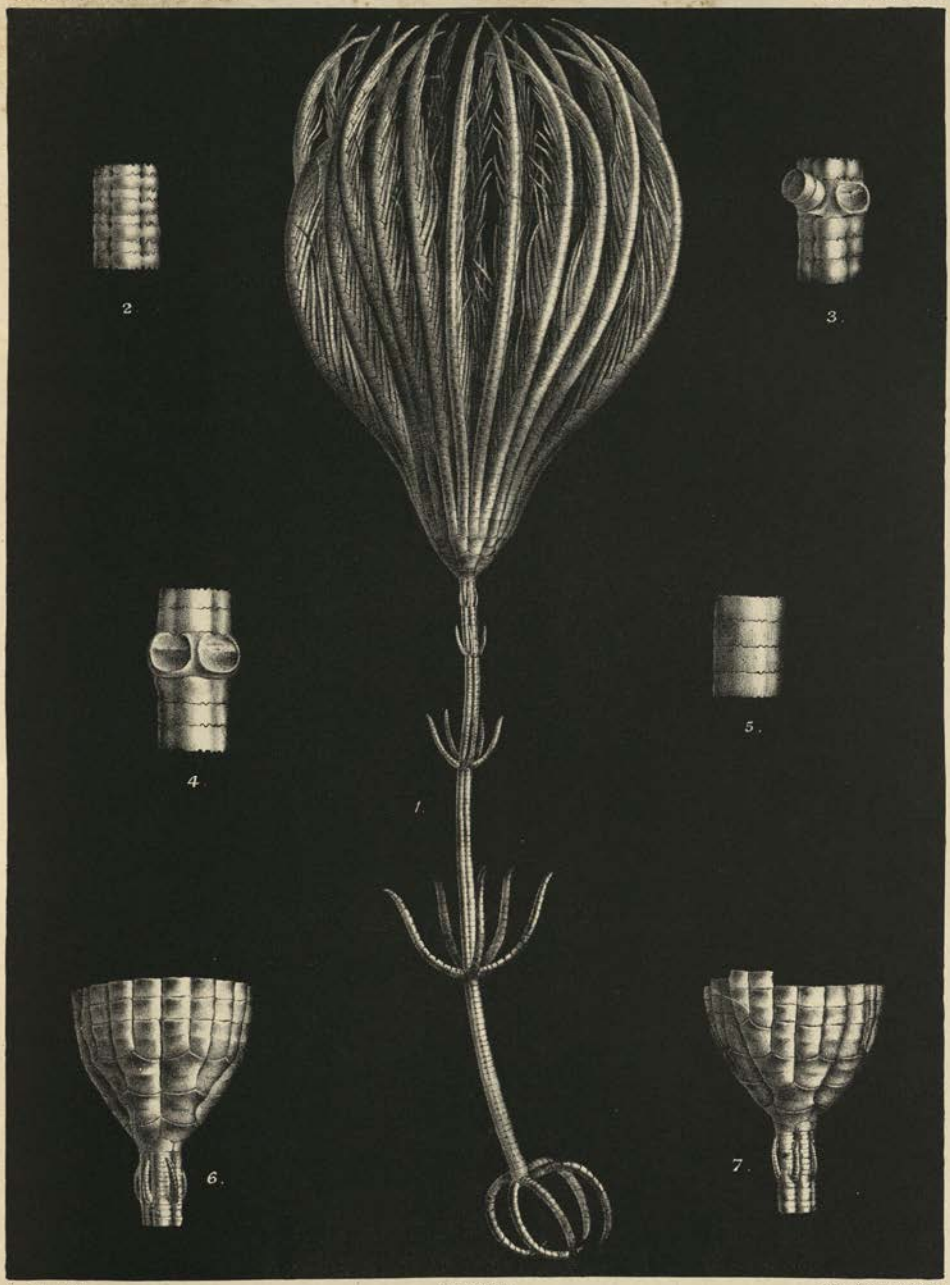
PENTACRINUS WYVILLE-THOMSONI, Jeffreys.

PLATE XIX.

PLATE XIX

PENTACRINUS WYVILLE-THOMSONI, Jeffreys.

			Diam.	Page
Fig. 1.	An entire specimen,	nat.	size	313
Fig. 2.	Portion of an internode from near the top of the stem,	×	4	18
Fig. 3.	Nodal and internodal joints from the upper part of the stem,	×	4	14
Fig. 4.	Nodal and internodal joints from the lower part of the stem,	×	4	14
Fig. 5.	Portion of an internode from the lower part of the stem,	×	4	17
Fig. 6.	Interradial view of the calyx and arm-bases,	×	2	320
Fig. 7.	Radial view of the same parts in another specimen,	×	2	320



Geo. West lith. W.B.C. dir. West Newman & Co imp.

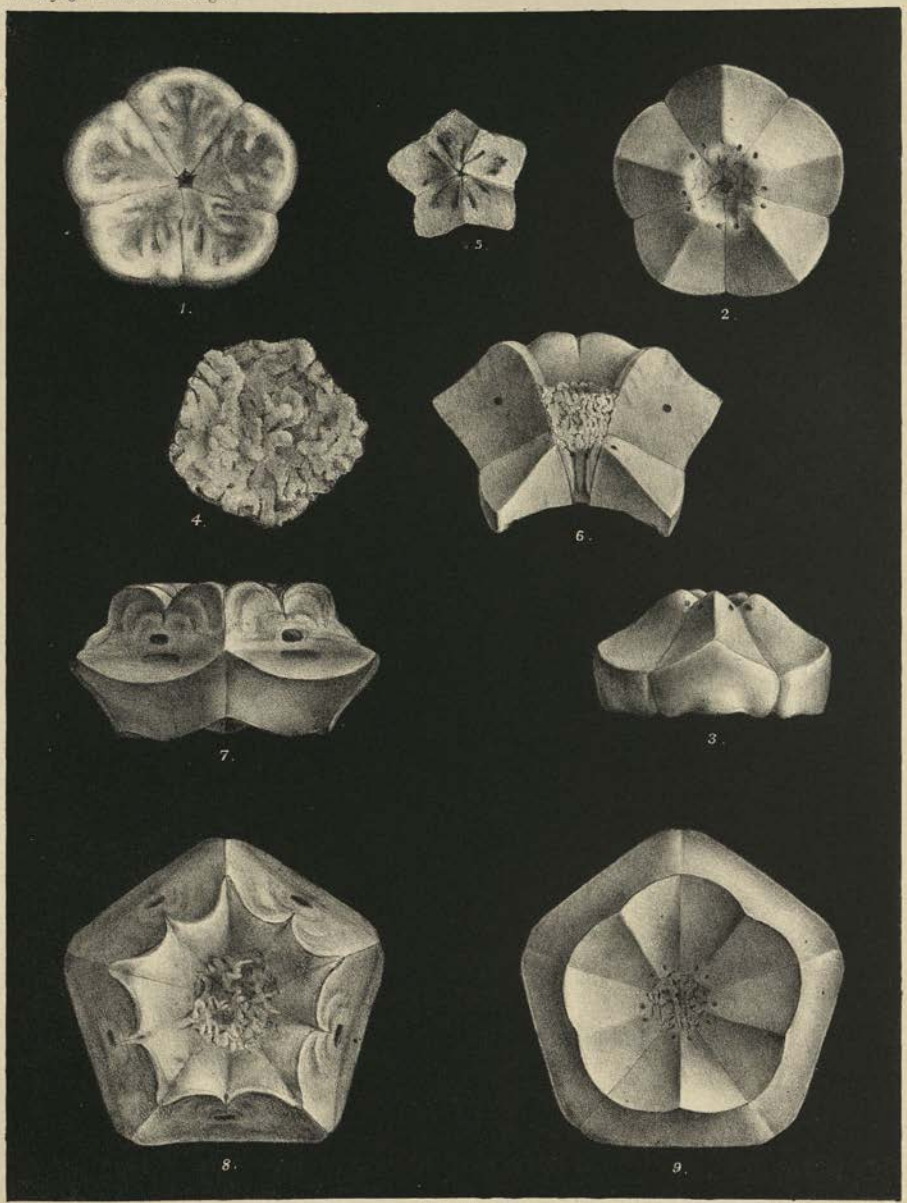
PENTACRINUS WYVILLE—THOMSONI, Jeffreys.

PLATE XX.

PLATE XX.

PENTACRINUS WYVILLE-THOMSONI, Jeffreys.

		Diam.	Page
Figs. 1–3. The ring of united basals,	×	10	282
Fig. 1. From below.			
Fig. 2. From above.			
Fig. 3. From the side.			
Fig. 4. The central plug of limestone network within the calyx; from above,	×	20	34
Fig. 5. The same; from below,	×	10	34
Fig. 6. Interior view of the calyx, after removal of two radials and one basal,	×	10	34
Figs. 7–9. The ring of united radials,	×	10	33
Fig. 7. From the side.			
Fig. 8. From above.			
Fig. 9. From below.			



Geo. West lith. W.B.C. dir. West Newman & Cº imp.

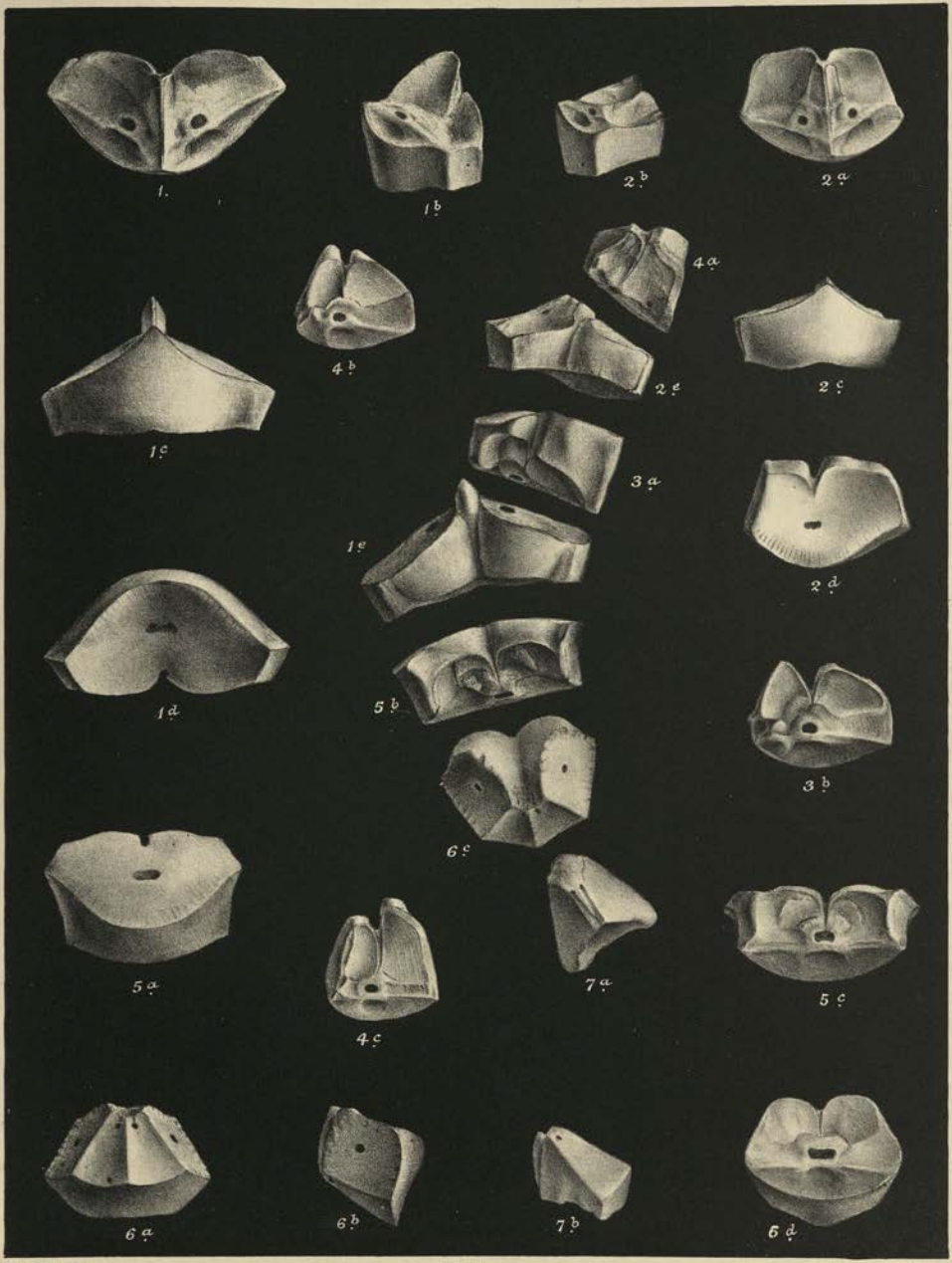
PENTACRINUS WYVILLE-THOMSONI, Jeffreys.

PLATE XXI.

PLATE XXI.

PENTACRINUS WYVILLE-THOMSONI, Jeffreys.

			Diam.	Page
Fig. 1.	A third or axillary radial,	×	10	313
	a. Distal face,			9
	b. Side view,			38
	c. Dorsal view,			
	d. Proximal face,			50
	e. Ventral surface,			
Fig. 2.	A second or axillary distichal,	×	10	313
	a. Distal face,			9
	b. Side view,			38
	c. Dorsal view,			
	d. Proximal face,			50
	e. Ventral surface,			
Fig. 3.	A first distichal,	×	10	313
	a. Ventral surface,			
	b. Proximal face,			38
Fig. 4.	A first brachial,	×	10	
	a. Ventral surface,			
	b. Proximal face,			38
	c. The proximal face of another specimen,			38
Fig. 5.	A second radial,	×	10	313
	a. Distal face,			50
	b. Ventral surface,			
	c. Proximal face,			9
Fig. 6.	A first radial,	×	10	313
	a. From beneath,			125
	b. Side view,			125
	c. From above,			125
	d. Distal face,			9
Fig. 7.	An isolated basal,	×	10	313
	a. From beneath,			293
	b. Side view,			125



Geo. West. lith. W.B.C. dir. West Newman & Co. imp.

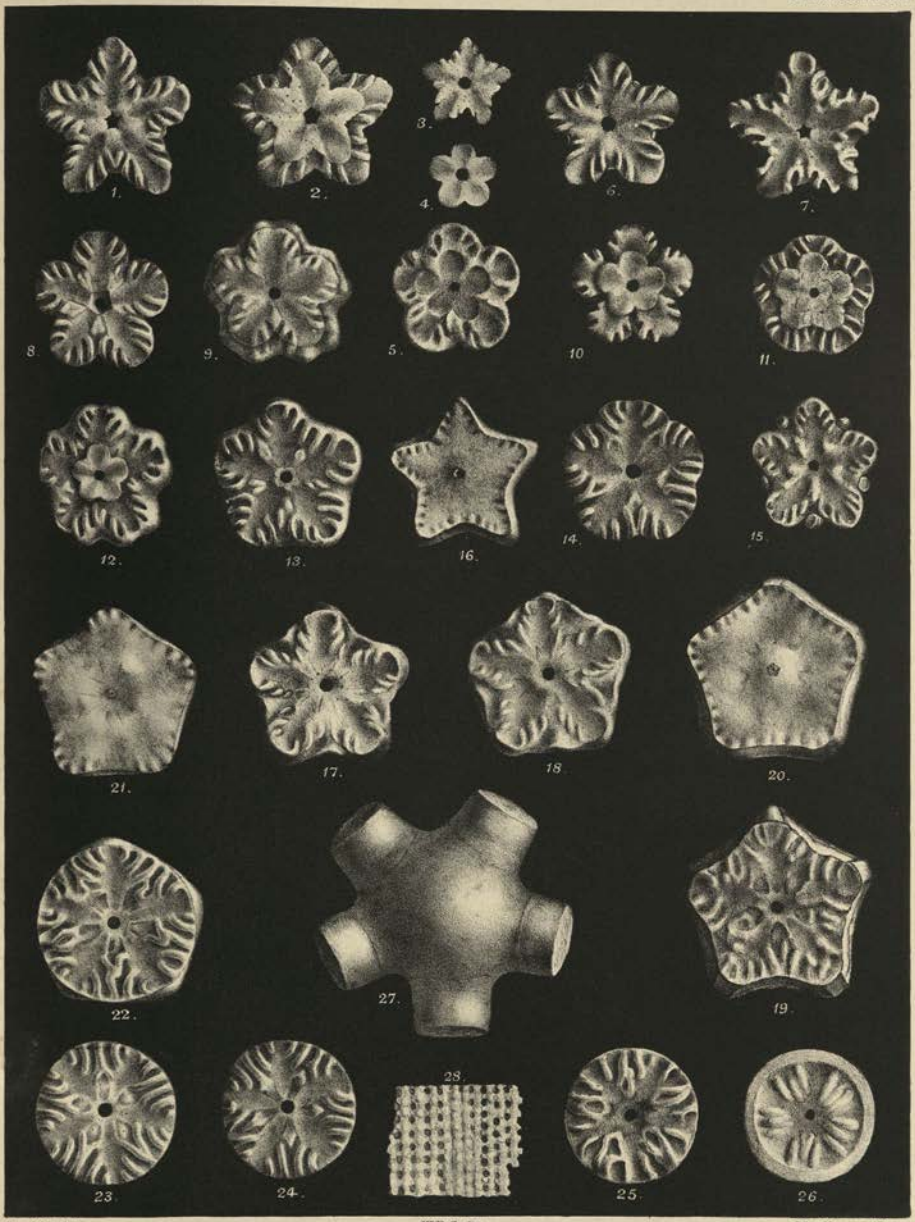
PENTACRINUS WYVILLE-THOMSONI, Jeffreys.

PLATE XXII.

PLATE XXII.

PENTACRINUS WYVILLE-THOMSONI, Jeffreys.

			Diam.	Page
Fig. 1.	One of the upper stem-joints,	×	10	17
Fig. 2.	The top stem-joint of a young specimen with a smaller one interpolated above it,	×	15	16
Fig. 3.	A small interpolated joint,	×	10	16
Fig. 4.	Another interpolated joint, somewhat younger,	×	10	16
Fig. 5.	An older joint from the upper part of the stem, with an impression on its upper surface in which rested the young joint shown in fig. 4,	×	10	16
Fig. 6.	The upper face of a young nodal joint,	×	10	17
Fig. 7.	A young internodal joint,	×	10	17
Fig. 8.	A somewhat older internodal joint,	×	10	17
Figs. 9–12.	Young internodal joints from the growing part of the stem, with smaller ones interpolated above them at different stages of development,	×	10	16
Fig. 13.	An older, but still immature internodal joint,	×	10	15
Fig. 14.	A young internodal joint from the upper part of the stem,	×	10	15
Fig. 15.	Upper face of a young nodal joint from the upper part of the stem,	×	10	17
Fig. 16.	Lower or syzygial face of a nodal joint from the middle of the stem,	×	10	17
Fig. 17.	Lower face of a supra-nodal joint from the upper part of the stem,	×	10	14
Fig. 18.	Upper face of the corresponding nodal joint,	×	10	14
	Figs. 19–24. Mature joints from a little below the middle of the stem.			
Fig. 19.	Upper face of a nodal joint,	×	10	17
Fig. 20.	Its lower or syzygial face,	×	10	17
Fig. 21.	The upper face of an infra-nodal joint,	×	10	14
Fig. 22.	Its lower face,	×	10	14
Figs. 23, 24.	Ordinary internodal joints,	×	10	17
Figs. 25, 26.	Old internodal joints from the lowest part of the stem,	×	10	17
Fig. 27.	An enlarged nodal joint from the end of the stem with its lower face rounded and the central canal closed up,	×	9	19
Fig. 28.	Portion of the calcareous network forming the substance of the stem-joints,			



Geo. West lith. W.B.C. dir. West Newman & Co.t imp.

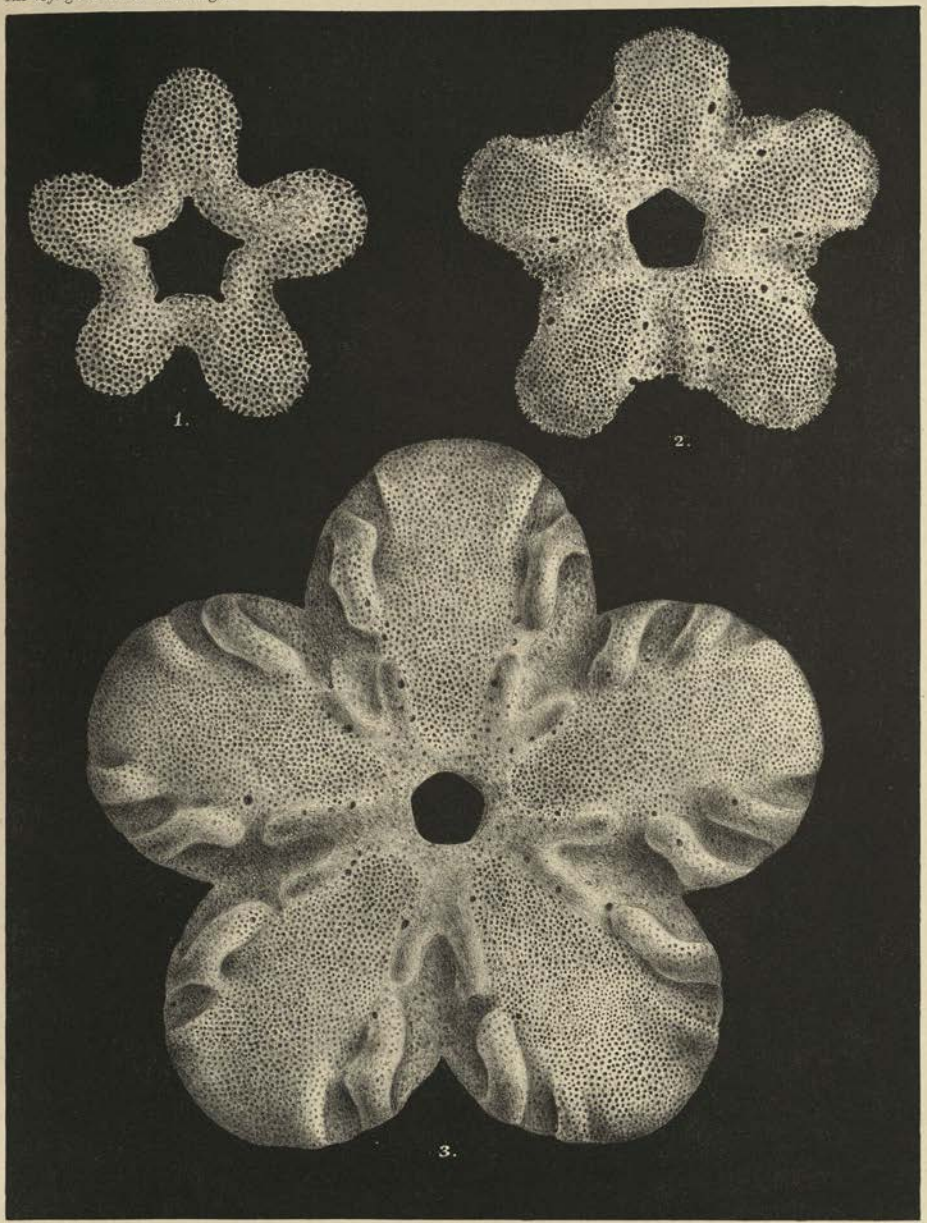
PENTACRINUS, WYVILLE-THOMSONI, Jeffreys

PLATE XXIII.

PLATE XXIII.

PENTACRINUS WYVILLE-THOMSONI, Jeffreys.

		Diam.	Page
Figs. 1, 2. Young interpolated joints from near the top of the stem, .	×	60	16
Fig. 3. A somewhat older, but still quite immature joint, . .	×	60	17



Geo. West lith. W. B. C. dir. West Newman & Cº imp.

PENTACRINUS WYVILLE-THOMSONI, Jeffreys.

PLATE XXIV.

PLATE XXIV.

The Lettering is the same in all the Figures.

A. Axial cord of the ray.
ai. Primary interradial cords.
ar. The secondary (radial) cords resulting from their bifurcation.
B. Basal.
ca. Fibrillar sheath round vascular axis of stem.
'ca'. Its radiating extensions.
cco. Interradial portion of the circular commissure.
ch. Cavities of the chambered organ.
ch'. Their downward prolongations into the stem.
chc. Fibres of connective tissue which traverse the fibrillar envelope of the chambered organ.
chn. The nodal enlargements of the peripheral vessels of the stem (*ch'*).
cv. Cirrus-vessel.
ico. Intra-radial portion of the circular commissure.
L. Interradial ligament.
l. Basiradial ligament.
lb. Interbasal ligament.
ld. Dorsal ligament.
ls. Interarticular ligament of stem.
p. Pigment granules.
R_1. First radial.
rp. Plug of calcareous tissue occupying the central funnel of the calyx.
V. Central vascular axis of stem.
X. Plexiform gland.

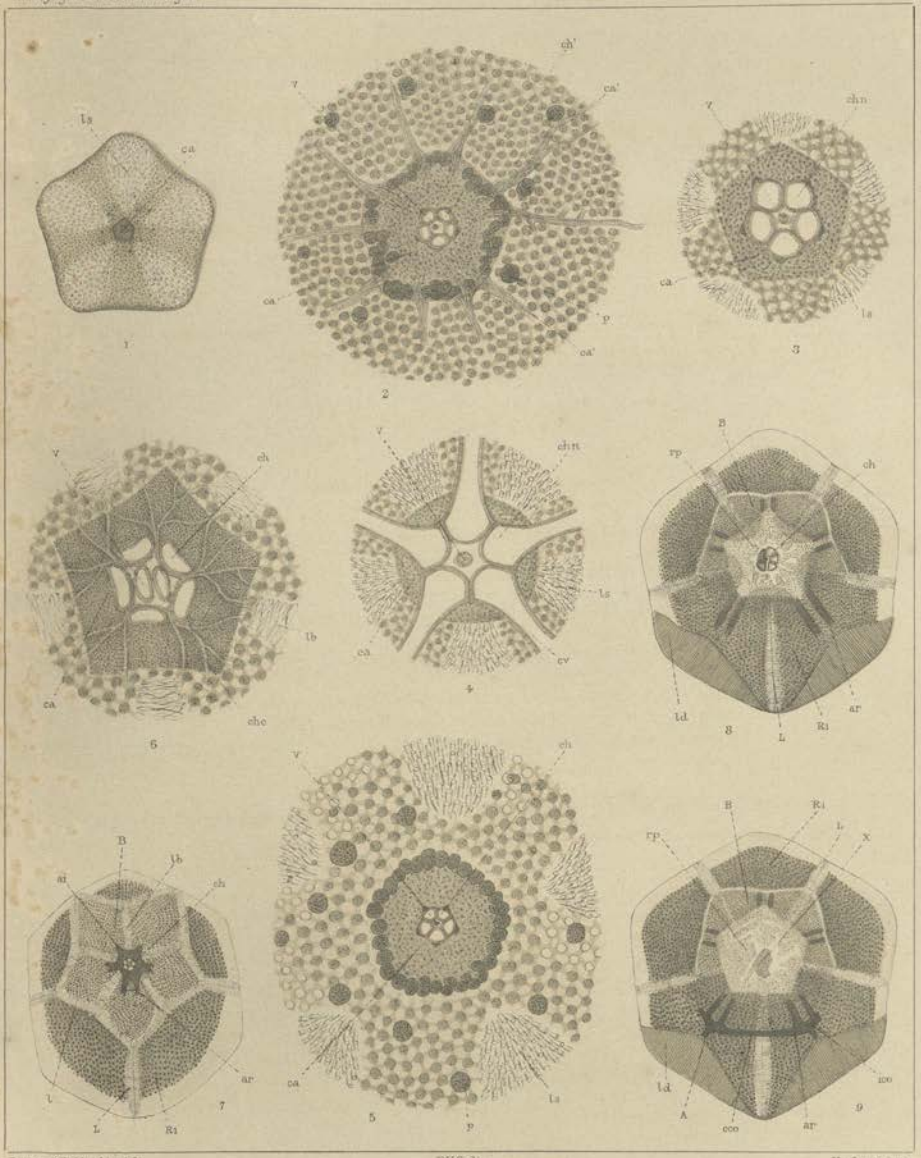
PENTACRINUS WYVILLE-THOMSONI, Jeffreys.

		Diam.	Page
Fig. 1. Horizontal section of an upper internodal joint, . .	×	15	23
Fig. 2. The central part of the same section, enlarged, . .	×	90	120
Fig. 3. Horizontal section through the upper part of a nodal joint, .	×	90	107
Fig. 4. Horizontal section of a nodal joint at the origin of the cirrus-vessels, ...	×	90	107
Fig. 5. The central part of a horizontal section through an internodal joint near the top of the stem, ...	×	90	23

In this figure *ch* should be *ch'*, as in fig. 2.

Figs. 6–9. Four out of a series of nearly horizontal sections through the calyx.

Fig. 6. The centre of a section through the lower part of the basal ring, ...	×	90	105
Fig. 7. Section through the upper part of the basal ring, . .	×	12	124
Fig. 8. Section through the lower part of the radials, ...	×	12	125
Fig. 9. Section through the middle of the radials, . . .	×	12	125



Bergeon & Highley del. et lith. P.H.C. dir. Hanhart imp.

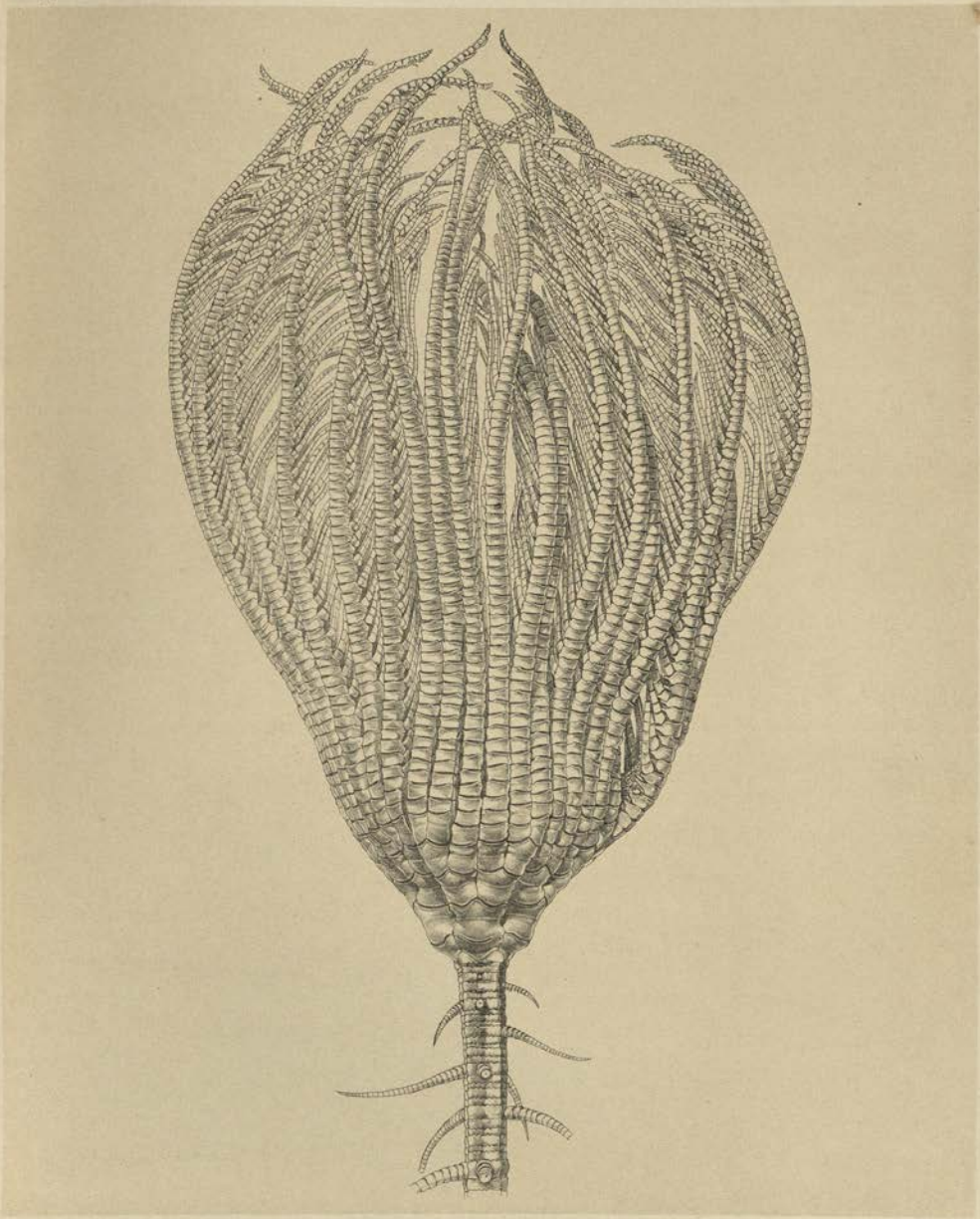
PENTACRINUS WYVILLE-THOMSONI, Jeffreys.

PLATE XXV.

PLATE XXV.

PENTACRINUS ALTERNICIRRUS, n. sp.

		Diam.	Page
Head and upper part of stem, ...	×	2	321



W. S. Black del.

F. Huth, Lith. Edin.

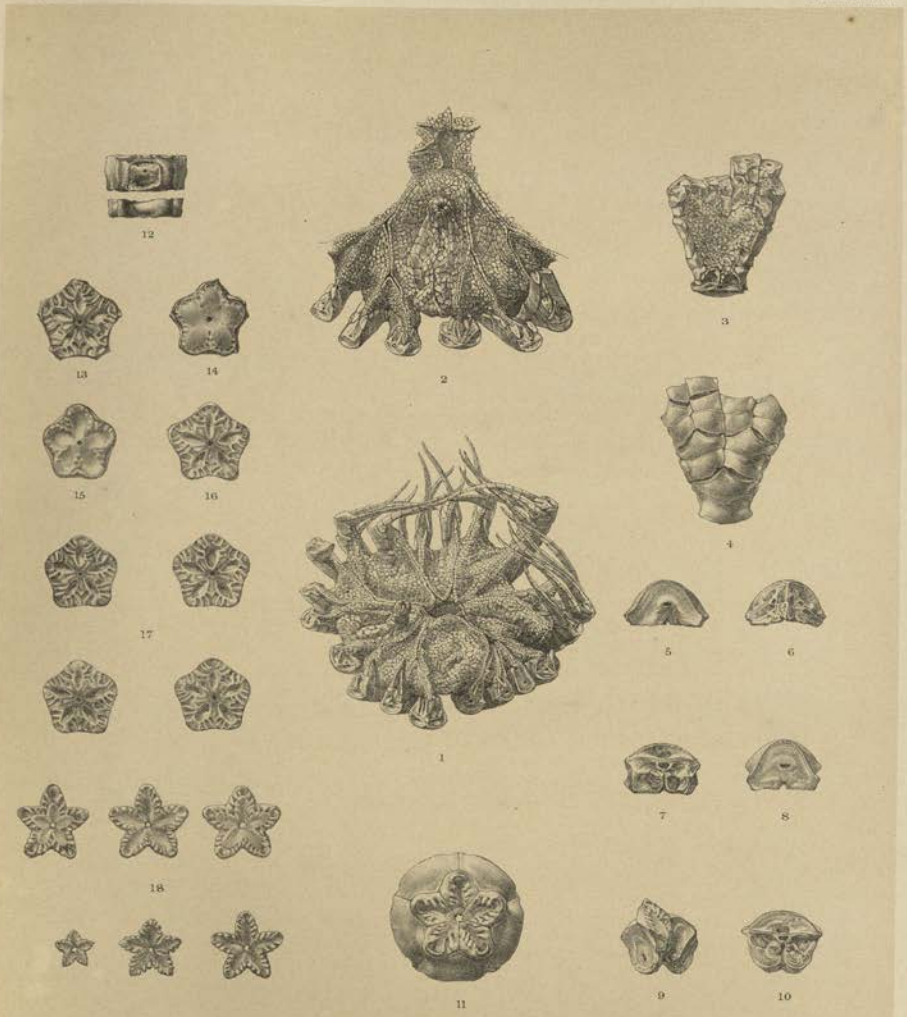
PENTACRINUS ALTERNICIRRUS, Sp. n.

PLATE XXVI.

PLATE XXVI.

PENTACRINUS ALTERNICIRRUS, n. sp.

		Diam.	Page
Fig. 1. The disk,	×	3	77
Fig. 2. The anal interradius, enlarged,	×	5	77
Figs. 3, 4. Inner and outer surfaces of the two outer radials with the distichals and palmars attached,	×	3	50
Figs. 5, 6. The third or axillary radial, Fig. 5. Proximal face. Fig. 6. Distal face.	×	3	5
Figs. 7, 8. The second radial, Fig. 7. Proximal face. Fig. 8. Distal face.	×	3	5
Fig. 9. The lower face of a first radial, with one basal remaining attached,	×	3	293
Fig. 10. Distal face of a first radial,	×	3	9
Fig. 11. The calyx from below,	×	3	33
Fig. 12. Side view of a nodal and infra-nodal joint in their relative positions,	×	4	13
Figs. 13, 14. Upper and lower faces of a nodal joint,	×	4	323
Figs. 15, 16. Upper and lower faces of the infra-nodal joint,	×	4	13
Fig. 17. Faces of internodal joints,	×	4	12
Fig. 18. Various stages in the development of internodal joints,	×	4	12



W.S. Blacke, del.

PENTACRINUS ALTERNICIRRUS, Sp. n.

J. Bell, Lith. Edin.

PLATE XXVII.

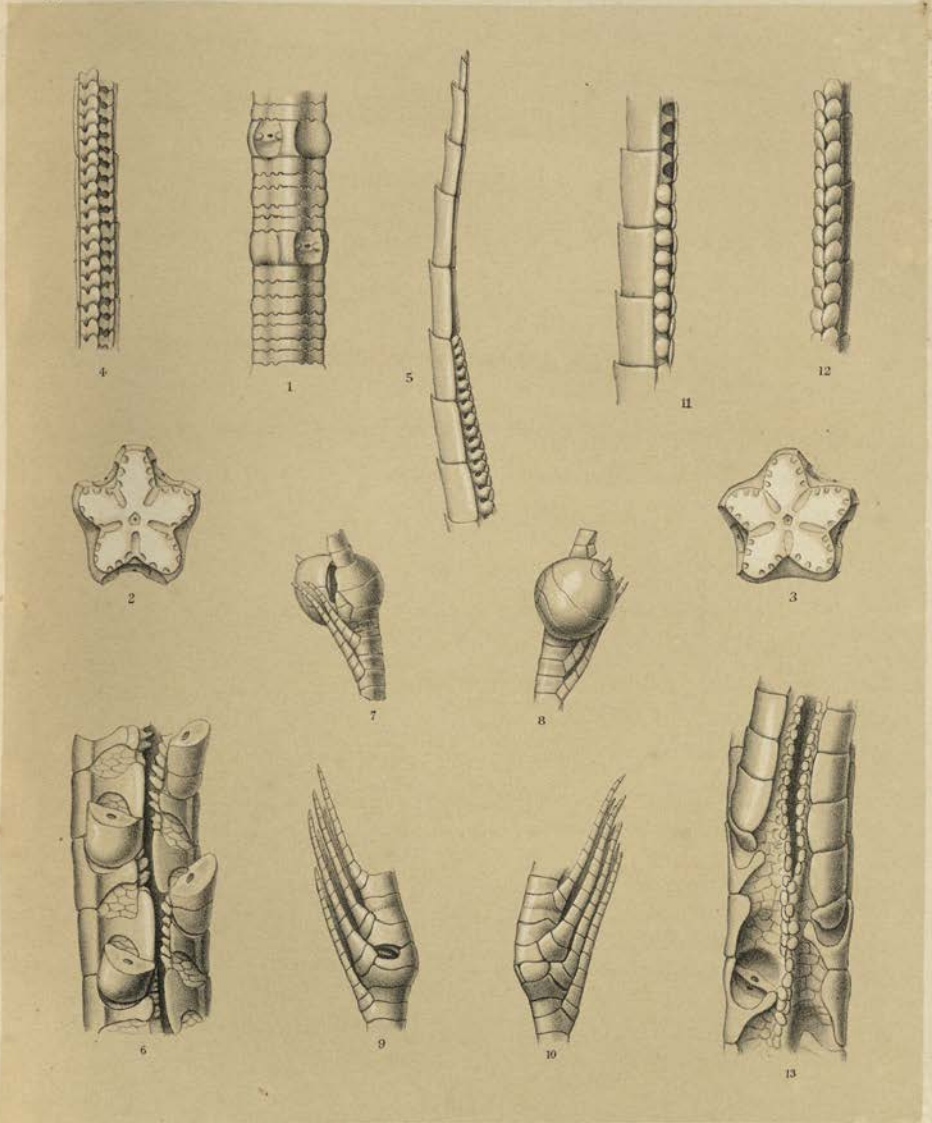
PLATE XXVII.

Figs. 1–10. PENTACRINUS ALTERNICIRRUS, n. sp.

		Diam.	Page
Fig. 1. Portion of stem containing two nodal joints; interradial view,	×	3	270
Fig. 2. Lower or syzygial face of a nodal joint which bears three cirri,	×	6	323
Fig. 3. The corresponding face of a joint bearing only two cirri,	×	6	323
Fig. 4. The ambulacral skeleton of a pinnule; from above,	×	15	323
Fig. 5. The end of a pinnule; from the side,	×	12	80
Fig. 6. The arm-groove and brachial ambulacrum,	×	12	
Figs. 7, 8. Inner and outer sides of an arm, bearing a pinnule-cyst of *Myzostoma deformator*, von Graff,	×	3	324
Figs. 9, 10. Inner and outer sides of an arm, modified by a cyst of *Myzostoma pentacrini*, von Graff,	×	3	324

Figs. 11–13. PENTACRINUS NARESIANUS, n. sp.

Fig. 11. The ambulacral skeleton of a pinnule; from the side. Some of the covering plates have been removed,	×	15	78
Fig. 12. The same; from above,	×	12	78
Fig. 13. The brachial ambulacrum; from above,	×	12	78



Berjeau & Highley del. et lith. P.H.C. dir. Hanhart imp.

1-10. PENTACRINUS ALTERNICIRRUS, Sp.n.
11-13. " NARESIANUS, Sp.n.

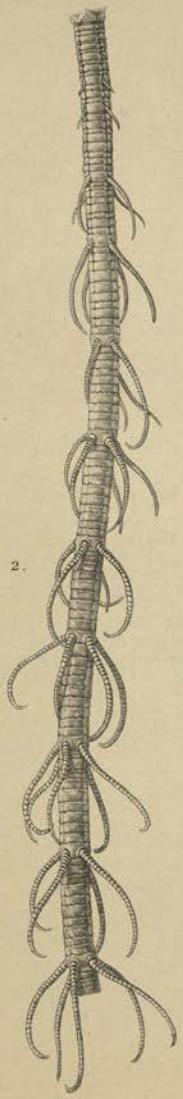
PLATE XXVIII.

PLATE XXVIII.

PENTACRINUS NARESIANUS, n. sp.

		Diam.	Page
Fig. 1. The head, ...	×	1¼	324
Fig. 2. The stem	×	1¼	324

1.



2.

W.S. Black, del. P. Roth, Lith. Edin.

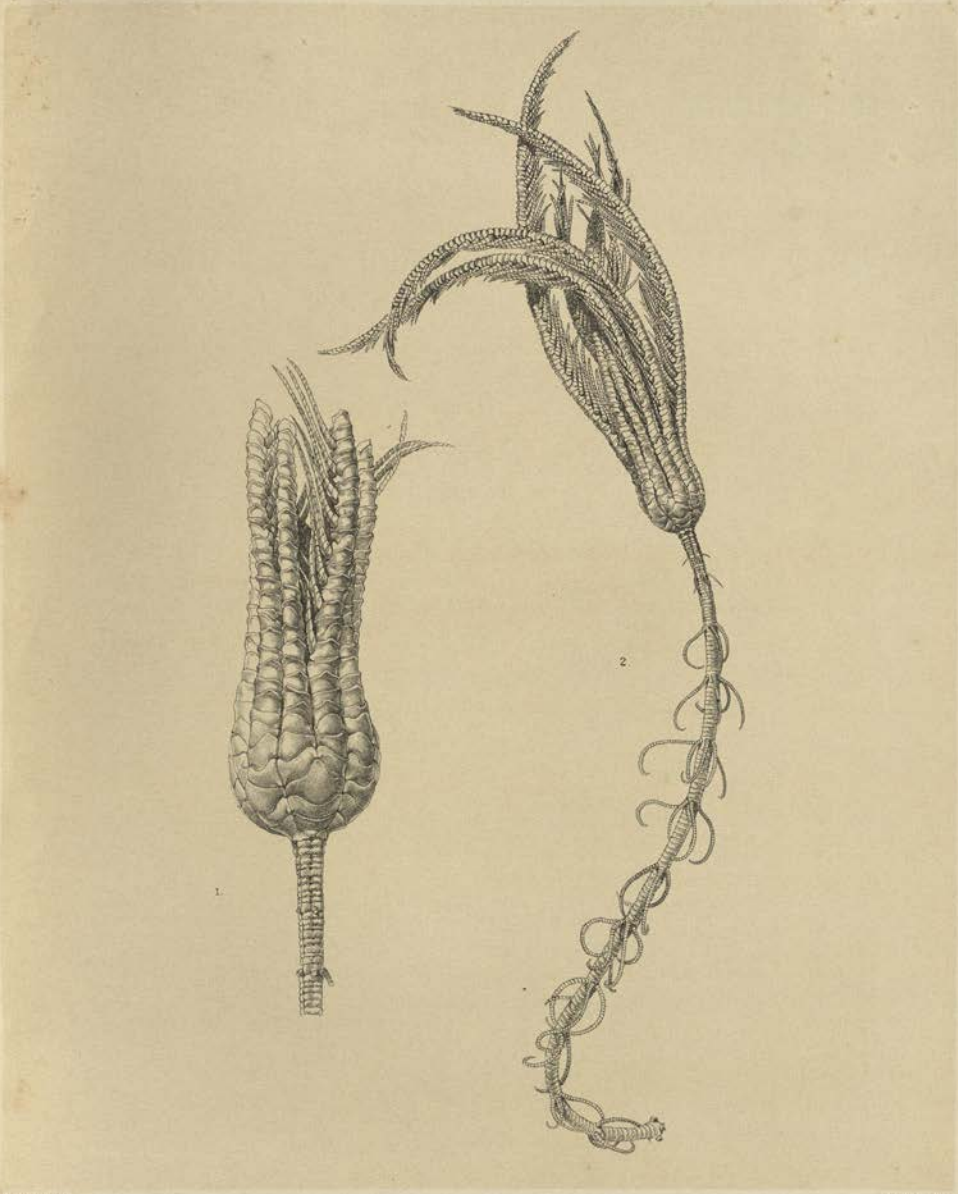
PENTACRINUS NARESIANUS, Sp. n.

PLATE XXIX.

PLATE XXIX.

PENTACRINUS NARESIANUS, n. sp.

		Diam.	Page
Fig. 1. The calyx and lower parts of the arms of an adult individual, .	×	2	326
Fig. 2. A young individual, ...	×	1¼	327



W. S. Black, del.

J. Roth, Lith. Edin.

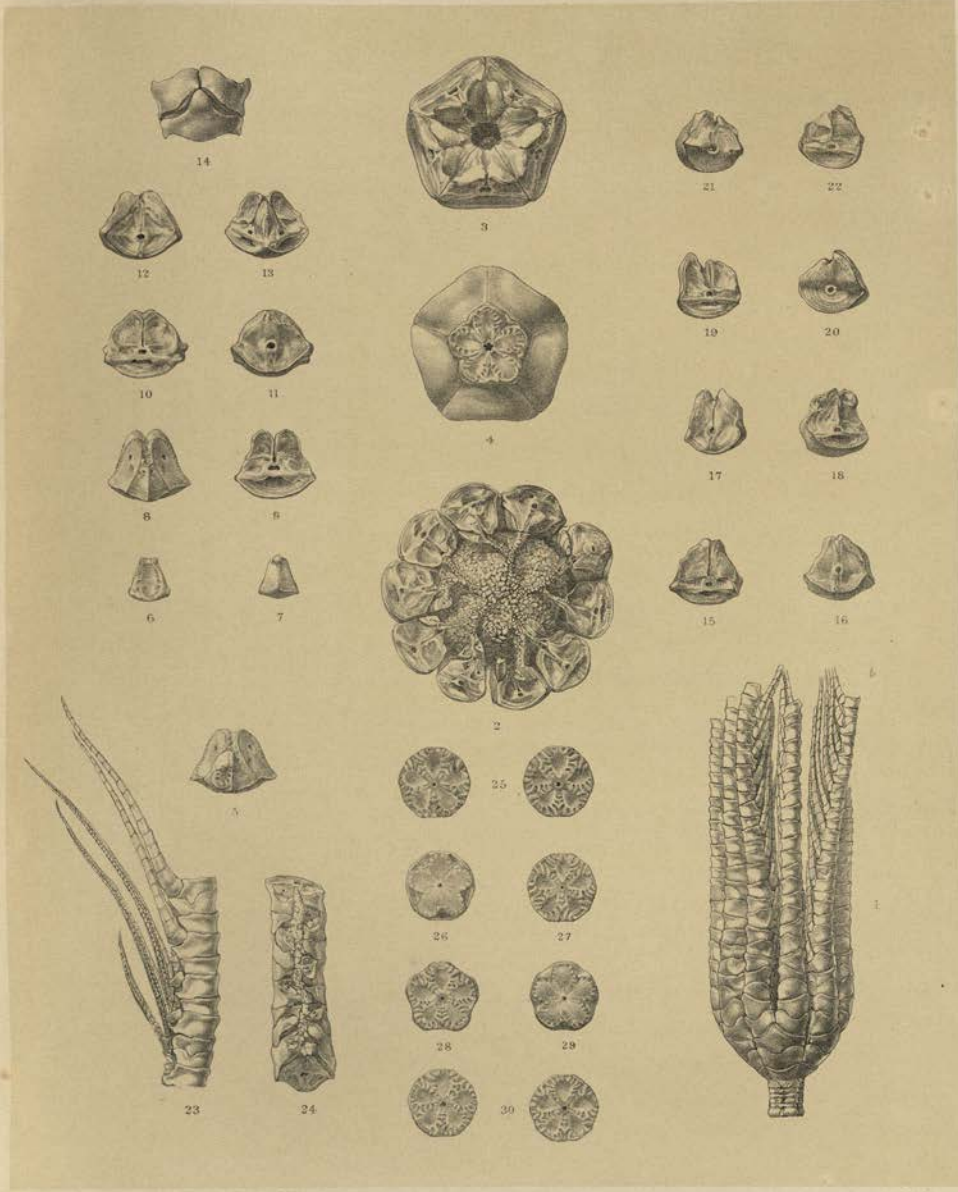
PENTACRINUS NARESIANUS, Sp. n.

PLATE XXX.

PLATE XXX.

PENTACRINUS NARESIANUS, n. s

		Diam.	Page
Fig. 1. The calyx and lower parts of the arms of an adult individual, .	×	2	326
Fig. 2. The disk, ...	×	3	77
Figs. 3, 4. The calyx; from above and below, ...	×	4	33
Fig. 5. The lower face of a first radial, with one basal remaining attached, ...	×	4	293
Figs. 6, 7. An isolated basal from below and above, . . .	×	4	293
Fig. 8. A first radial, from beneath, ...	×	4	293
Fig. 9. Distal face of a first radial, ...	×	4	9
Figs. 10, 11. Proximal and distal faces of a second radial, . .	×	4	326
Figs. 12, 13. Proximal and distal faces of a third or axillary radial, .	×	4	326
Fig. 14. Dorsal aspect of the axillary with the two first brachials attached, ...	×	4	326
Figs. 15, 16. Proximal and distal faces of a first brachial, . .	×	4	326
Figs. 17, 18. Proximal and distal faces of a second brachial, . .	×	4	326
Figs. 19, 20. Proximal and distal faces of the hypozygal portion of the third brachial, ...	×	4	326
Figs. 21, 22. Proximal and distal faces of the corresponding epizygal, .	×	4	326
Fig. 23. Portion of an arm containing two syzygies; side view, .	×	3	326
Fig. 24. The arm-groove and brachial ambulacrum; from above, .	×	3	78
Fig. 25. Terminal faces of an internodal joint, ...	×	5	12
Figs. 26, 27. Lower and upper faces of a nodal joint, . . .	×	5	13
Figs. 28, 29. Lower and upper faces of an infra-nodal joint, . .	×	5	13
Fig. 30. The two faces of the next joint below an infra-nodal, . .	×	5	12



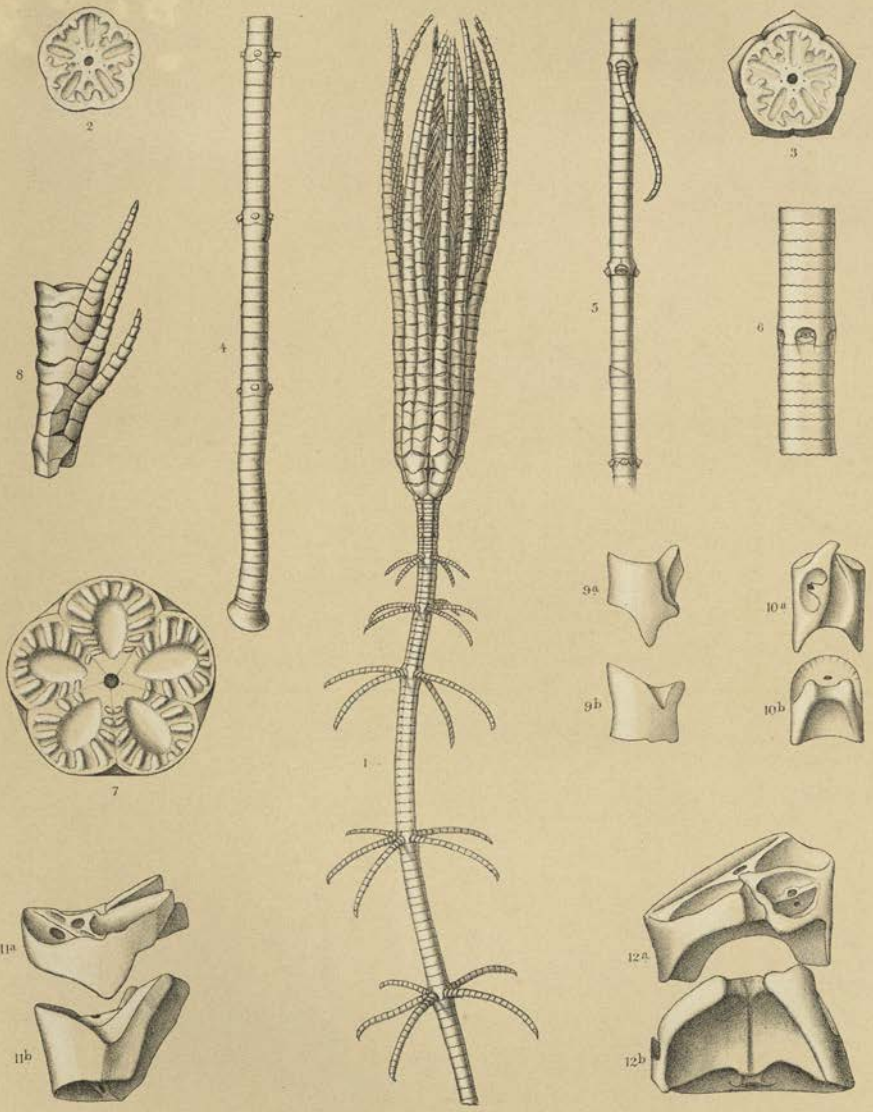
PENTACRINUS NARESIANUS, Sp. n.

PLATE XXXa.

PLATE XXXa.

PENTACRINUS NARESIANUS, n. sp.

		Diam.	Page
Fig. 1. The youngest specimen obtained, ...	×	2	327
Fig. 2. One of its internodal joints, ...	×	13	291
Fig. 3. One of its nodal joints; upper face, ...	×	13	291
Figs. 4, 5. Two fragments, probably from the lower part of the stem of this specimen, ...	×	3	327
Fig. 6. Portion of a full grown stem, ...	×	3	12
Fig. 7. One of its internodal joints, ...	×	10	327
Fig. 8. The inner face of an arm from the third to the eighth brachials,	×	3	326
Figs. 9, 10. Two syzygial joints from the arm of a young individual, as seen from the side (fig. 9) and from above (fig. 10), . *a.* The epizygal. *b.* The hypozygal.	×	10	327
Figs. 11, 12. Similar views of a full grown syzygial pair, . .	×	10	327



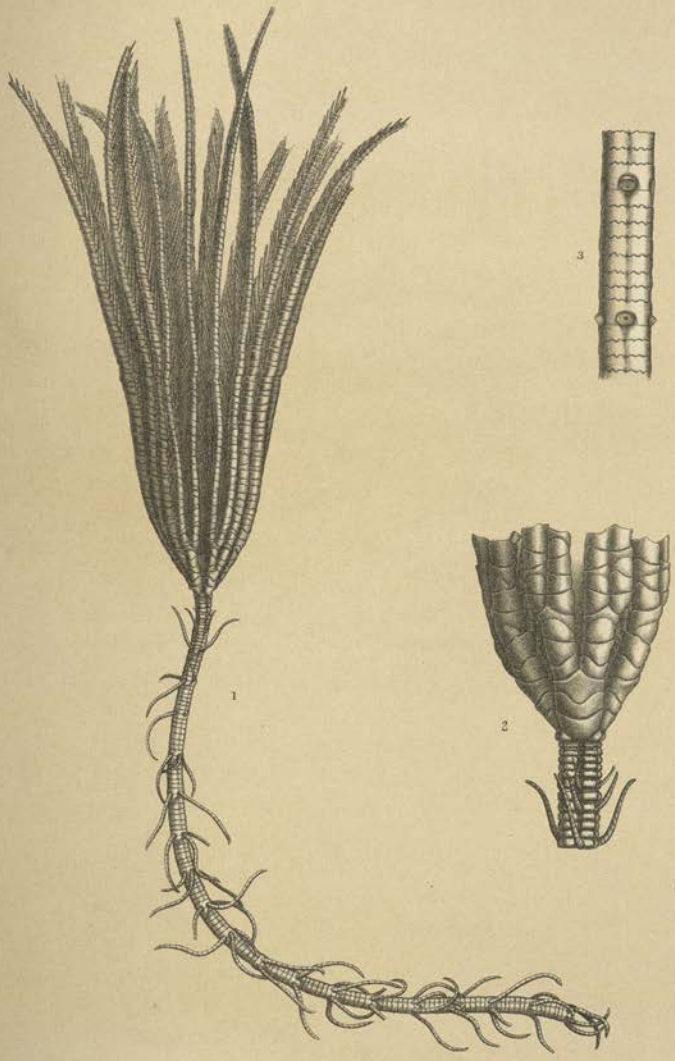
PENTACRINUS NARESIANUS, Sp. n.

PLATE XXXI.

PLATE XXXI.

PENTACRINUS BLAKEI, P. H. Carpenter.

	Diam.	Page
Fig. 1. An entire specimen, ...	nat. size	328
Fig. 2. The calyx and arm-bases, ...	× 3	330
Fig. 3. Portion of the stem, ...	× 3	329



Benjeau & Huxley del. et lith.

P.H.C. dir.

Hanhart imp.

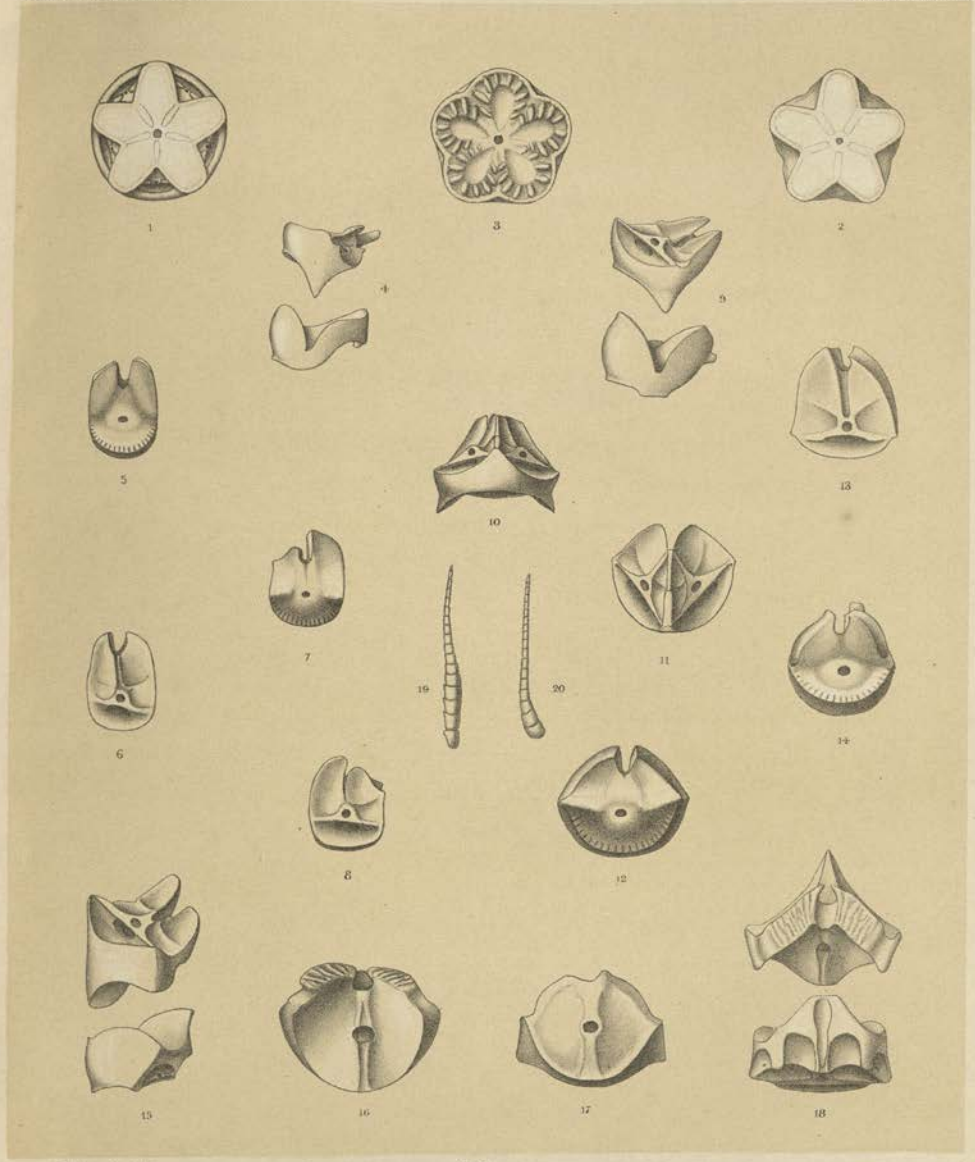
PENTACRINUS BLAKEI, Sp n.

PLATE XXXII.

PLATE XXXII.

PENTACRINUS BLAKEI, P. H. Carpenter.

		Diam.	Page
Fig. 1.	The lower or syzygial face of a nodal joint, . . . ×	7	14
Fig. 2.	The upper face of the corresponding infra-nodal, . . ×	7	13
Fig. 3.	Face of an internodal joint, ... ×	7	335
Fig. 4.	The two elements of a brachial syzygy in their relative positions; side view, ... ×	7	330
Figs. 5, 6.	Distal and proximal faces of the hypozygal, . . . ×	7	330
Figs. 7, 8.	Proximal and distal faces of the epizygal, . . . ×	7	330
Fig. 9.	The two syzygial elements of a distichal axillary in their relative positions; side view, ... ×	7	330
Fig. 10.	Dorsal aspect of the epizygal, ... ×	7	11
Fig. 11.	Its distal face, ... ×	7	11
Fig. 12.	Its proximal face, ... ×	7	330
Fig. 13.	Proximal face of the hypozygal, ... ×	7	11
Fig. 14.	Its distal face, ... ×	7	330
Fig. 15.	Side view of the two outer radials in their relative positions, . ×	7	330
Fig. 16.	Proximal face of the axillary, ... ×	7	8
Fig. 17.	Distal face of the second radial, ... ×	7	8
Fig. 18.	Upper view of the two outer radials in their relative positions, ×	7	330
Fig. 19.	A lower pinnule, ... ×	3	328
Fig. 20.	An outer pinnule, ... ×	3	328



Bergeau & Highley del. et lith.

P.H.C. dir.

PENTACRINUS BLAKEI, Sp. n.

Hanhart imp.

PLATE XXXIII.

PLATE XXXIII.

Figs. 1–3. PENTACRINUS BLAKEI, P. H. Carpenter.

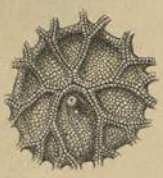
			Diam.	Page
Fig. 1.	The ambulacral skeleton of a pinnule; from the side, .	×	15	78
Fig. 2.	Portion of a ray, consisting of the two outer radials, the distichals, and the three lowest brachials; from the side, .	×	3	330
Fig. 3.	Portion of a brachial ambulacrum; from above, . .	×	12	78

Figs. 4–6. PENTACRINUS DECORUS, Wyv. Thoms.

Fig. 4.	Portion of a brachial ambulacrum; from above, . .	×	12	337
Fig. 5.	Vertical section of the calyx, passing a little to one side of the middle line; from a preparation made Dr. W. B. Carpenter,	×	8	293
Fig. 6.	Ventral aspect of one of the lower arm-divisions, showing the ambulacral skeleton, ...	×	7	337

Figs. 7–10. PENTACRINUS MOLLIS, n. sp.

Fig. 7.	The disk, ...	×	7	338
Fig. 8.	The calyx; from beneath, ...	×	6	338
Fig. 9.	The anterior and left antero-lateral rays, . . .	×	6	338
Fig. 10.	The right postero-lateral ray, ...	×	6	338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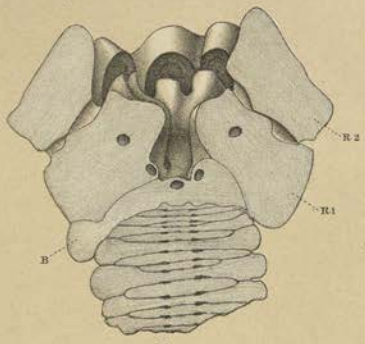

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Berjeau & Highley del. et lith. P.H.C. dir. Hanhart imp.

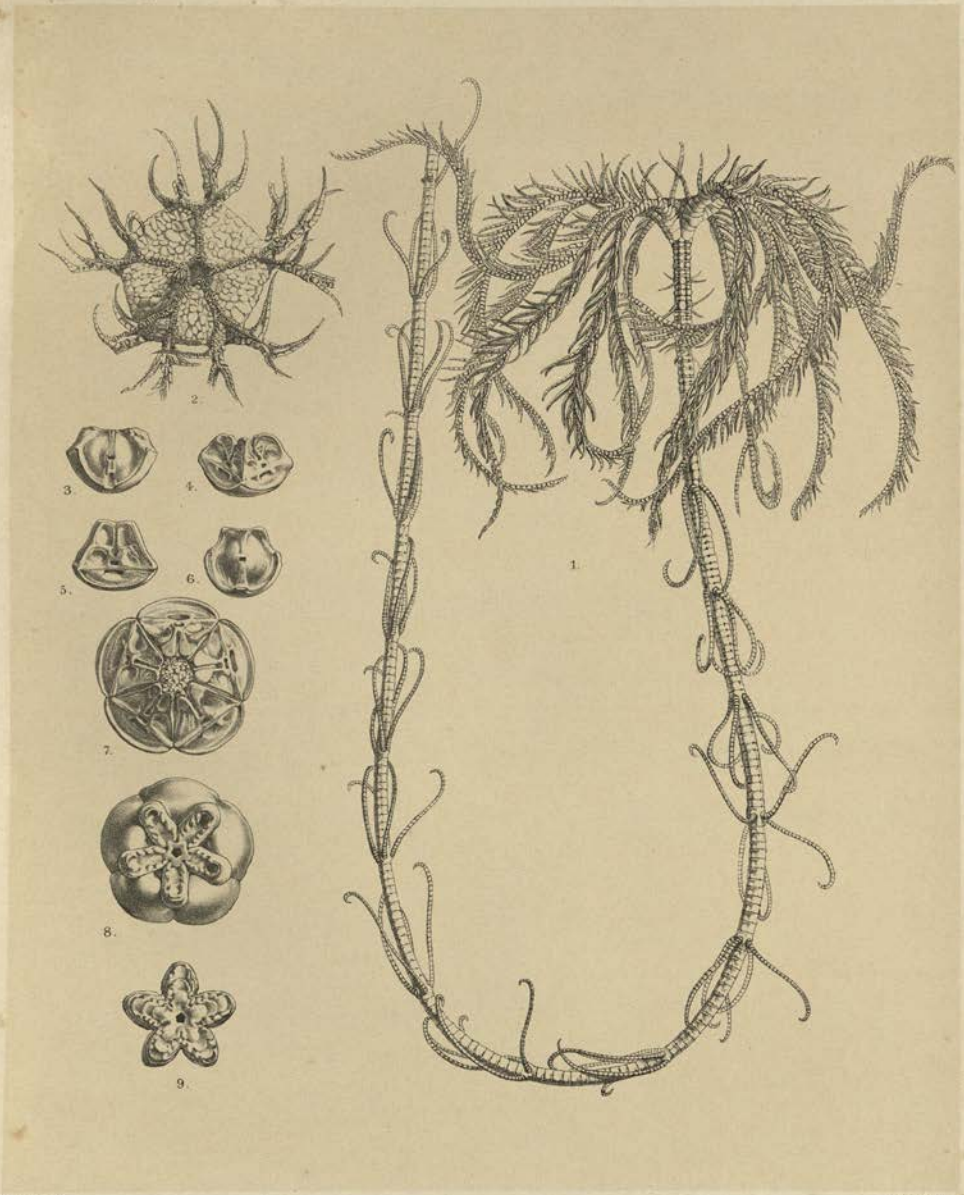
1-3. PENTACRINUS BLAKEI, Sp.n. 4-6. PENTACRINUS DECORUS, Wy.Th.
7-10. PENTACRINUS MOLLIS, Sp.n.

PLATE XXXIV.

PLATE XXXIV.

PENTACRINUS DECORUS, Wyv. Thoms.

		Diam.	Page
Fig. 1.	An entire specimen, ...	nat. size	330
Fig. 2.	The disk, ...	× 3	337
Figs. 3, 4.	Proximal and distal faces of the third or axillary radial, .	× 5	309
Figs. 5, 6.	Proximal and distal faces of the second radial, . .	× 5	309
Fig. 7.	The calyx; from above, ...	× 5	33
Fig. 8.	Inferior aspect of the calyx, ...	× 5	336
Fig. 9.	The uppermost stem-joint, ...	× 5	16



W. S. Black, del.

F. Huth, Lith^r Edin^r

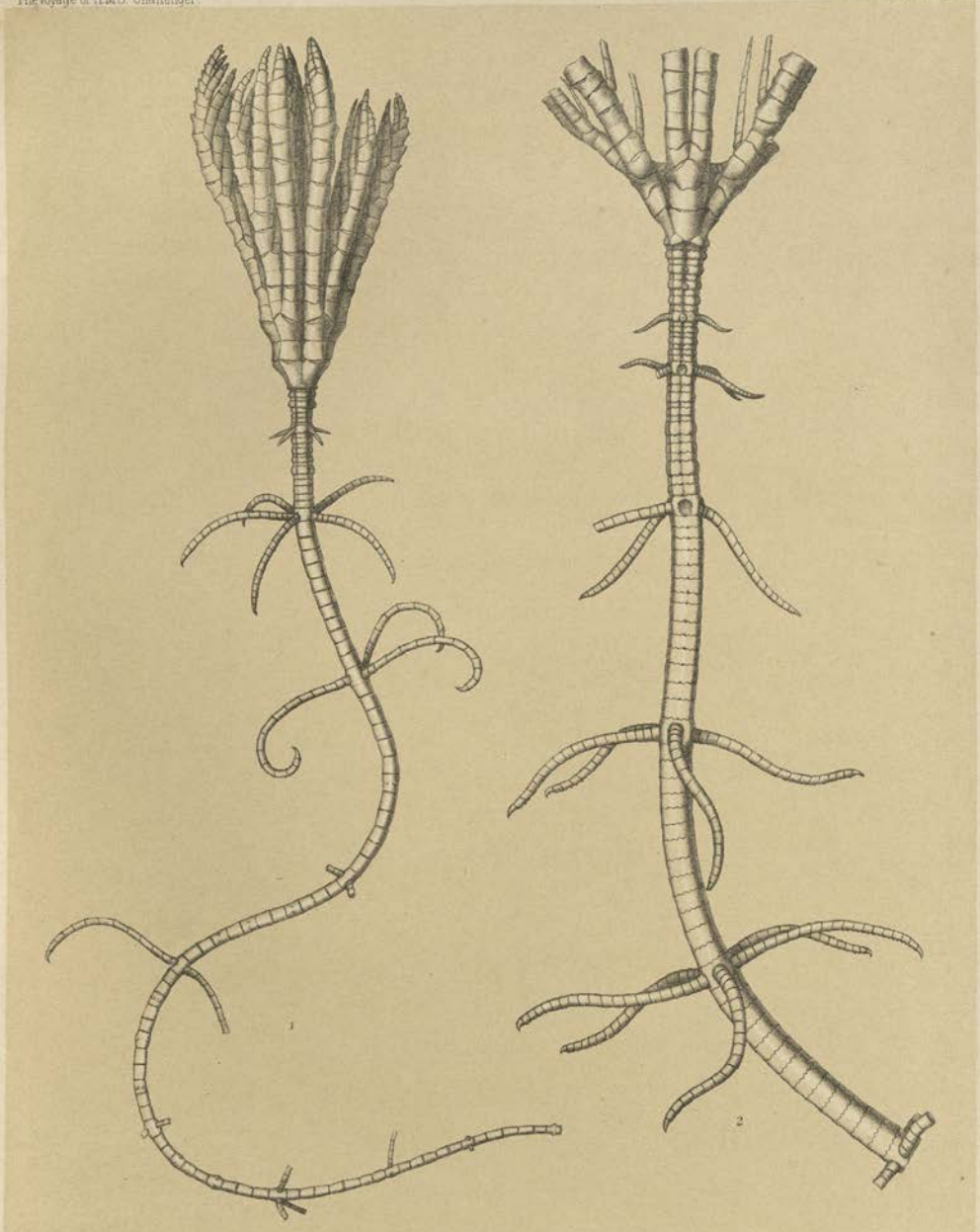
PENTACRINUS DECORUS, Wy. Th.

PLATE XXXV.

PLATE XXXV.

PENTACRINUS DECORUS, Wyv. Thoms.

		Diam.	Page
Fig. 1. The youngest specimen obtained by the "Blake," . . .	×	4	21
Fig. 2. A slightly older individual, ...	×	4	336



Berjeau & Highley del et lith. P.H.C. dir. Hanhart imp.

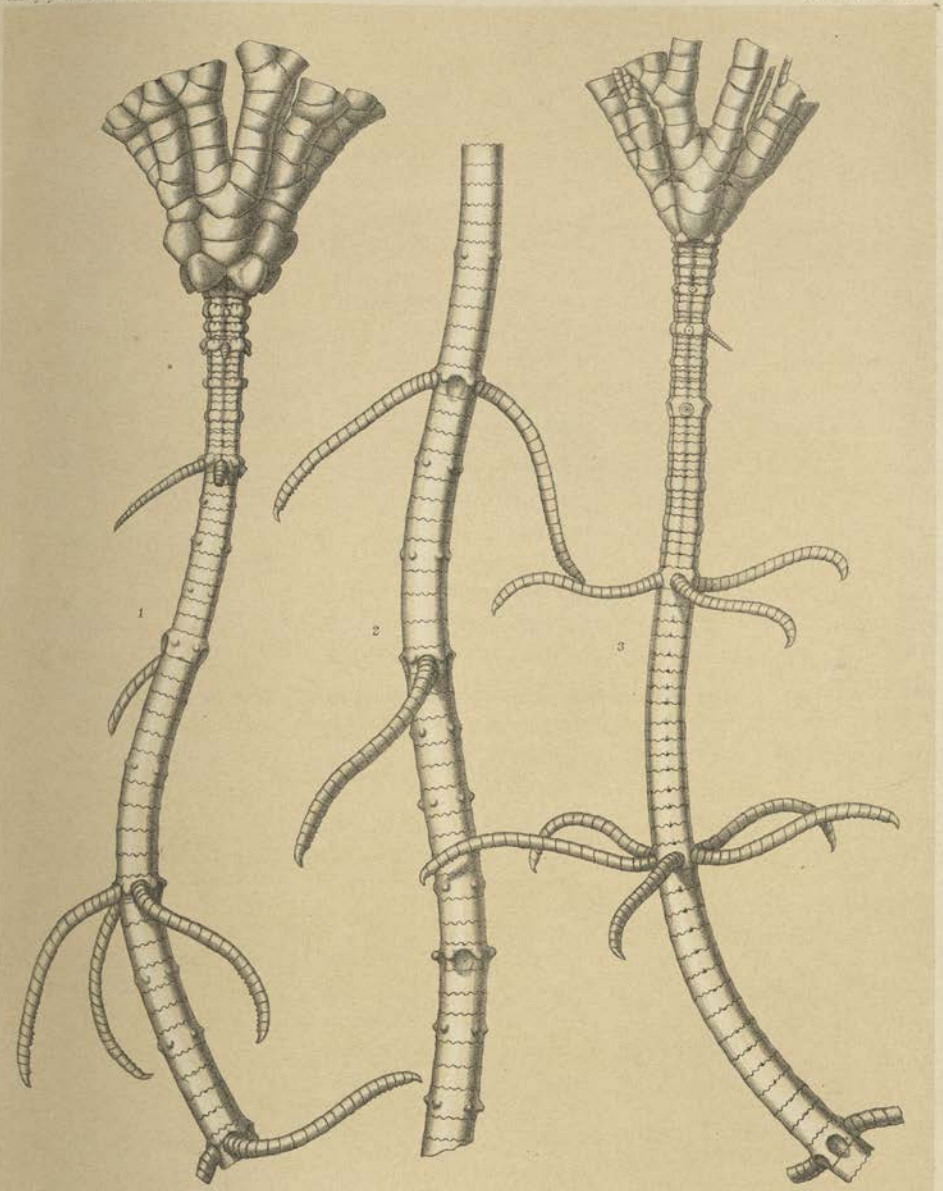
PENTACRINUS DECORUS, Wy. Th.

PLATE XXXVI.

PLATE XXXVI.

PENTACRINUS DECORUS, Wyv. Thoms.

		Diam.	Page
Fig. 1.	Calyx and arm-bases of a premature individual with large basals, ... ×	4	336
Fig. 2.	The lower part of the stem of the same specimen, . . ×	4	335
Fig. 3.	Calyx and arm-bases of another young individual with small basals, ... ×	4	336



Berjeau & Hashley del et lith.
P.H.C. dir.
Hanhart imp.

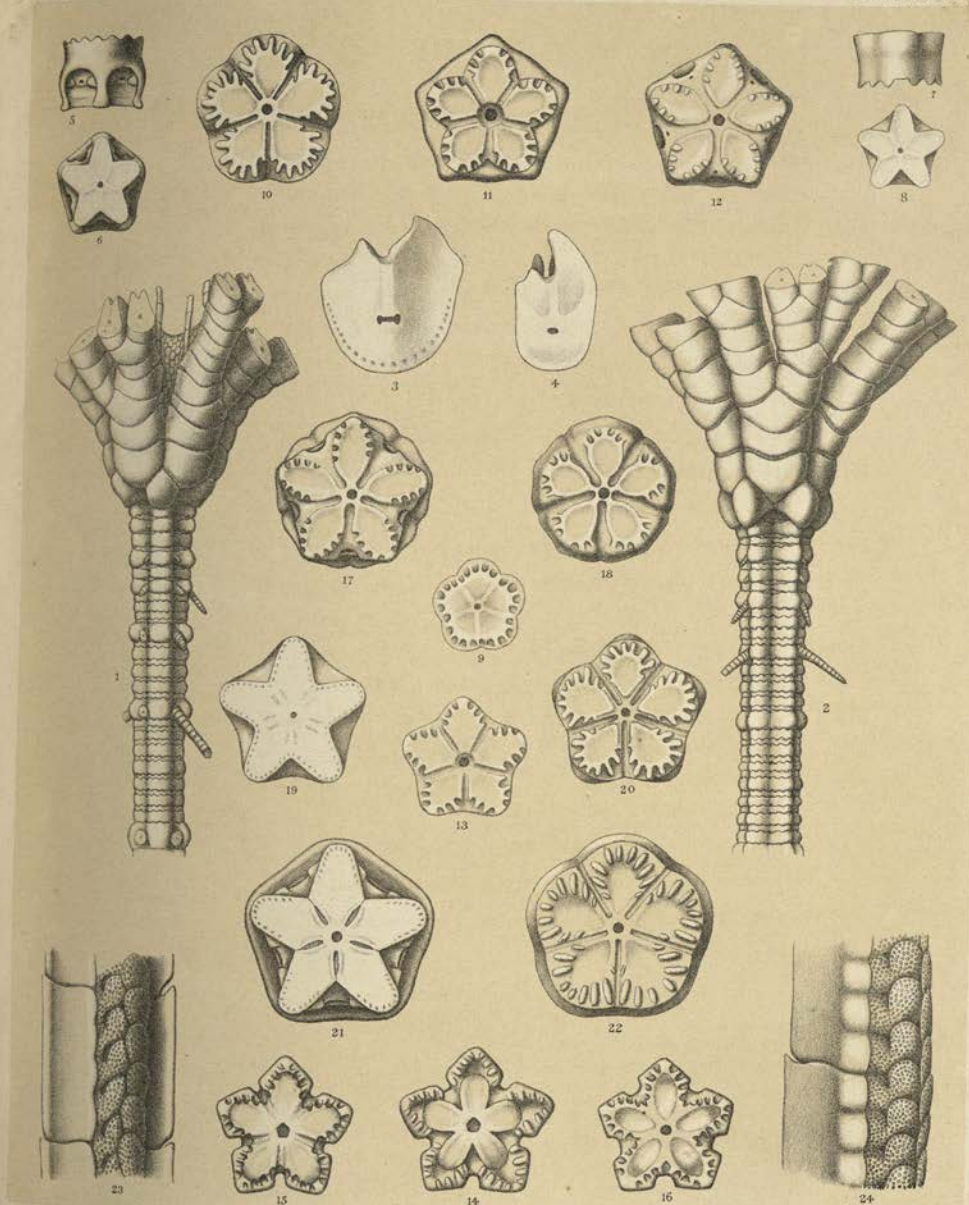
PENTACRINUS DECORUS, Wy. Th.

PLATE XXXVII.

PLATE XXXVII.

PENTACRINUS DECORUS, Wyv. Thoms.

			Diam.	Page
Fig. 1.	The calyx and arm-bases of a premature individual with large basals; interradial view,	×	4	336
Fig. 2.	Radial view of a similar specimen with no cirri on one face of the stem,	×	4	335
Fig. 3.	The syzygial face of one of the distichals,	×	10	334
Fig. 4.	The syzygial face of a brachial,	×	10	334
Fig. 5.	A nodal joint from a young stem; from the side,	×	10	291
Fig. 6.	The lower or syzygial face of the same joint,	×	10	13
Fig. 7.	Side view of an infra-nodal joint from a young stem,	×	10	13
Fig. 8.	Its upper or syzygial face,	×	10	13
Fig. 9.	One of the faces of an internodal joint from a young stem,	×	10	291
Fig. 10.	An interpolated joint from the growing part of the stem,	×	6	291
Fig. 11.	The upper face of a young nodal joint from the top of the stem,	×	7	17
Fig. 12.	Its lower or syzygial face,	×	7	17
Fig. 13.	A young internodal joint from near the top of the stem,	×	7	17
Fig. 14.	The upper face of a very young nodal joint with a small interpolated joint resting upon it,	×	7	16
Fig. 15.	Upper face of a young nodal joint with an interpolated joint lying on it, and almost concealing it,	×	7	16
Fig. 16.	The lower face of the same joint,	×	7	17
Figs. 17, 18.	The lower and upper faces of a premature nodal joint,	×	7	17
Fig. 19.	The upper or syzygial face of a mature infra-nodal joint,	×	6	334
Fig. 20.	Its lower face,	×	6	334
Fig. 21.	The lower or syzygial face of a mature nodal joint,	×	7	334
Fig. 22.	Its upper face,	×	7	335
Figs. 23, 24.	Portions of the ambulacral skeleton of two pinnules,	×	30	337



Benjeau & Highley delet lith.

P.H.C. dir.

PENTACRINUS DECORUS, Wy. Th.

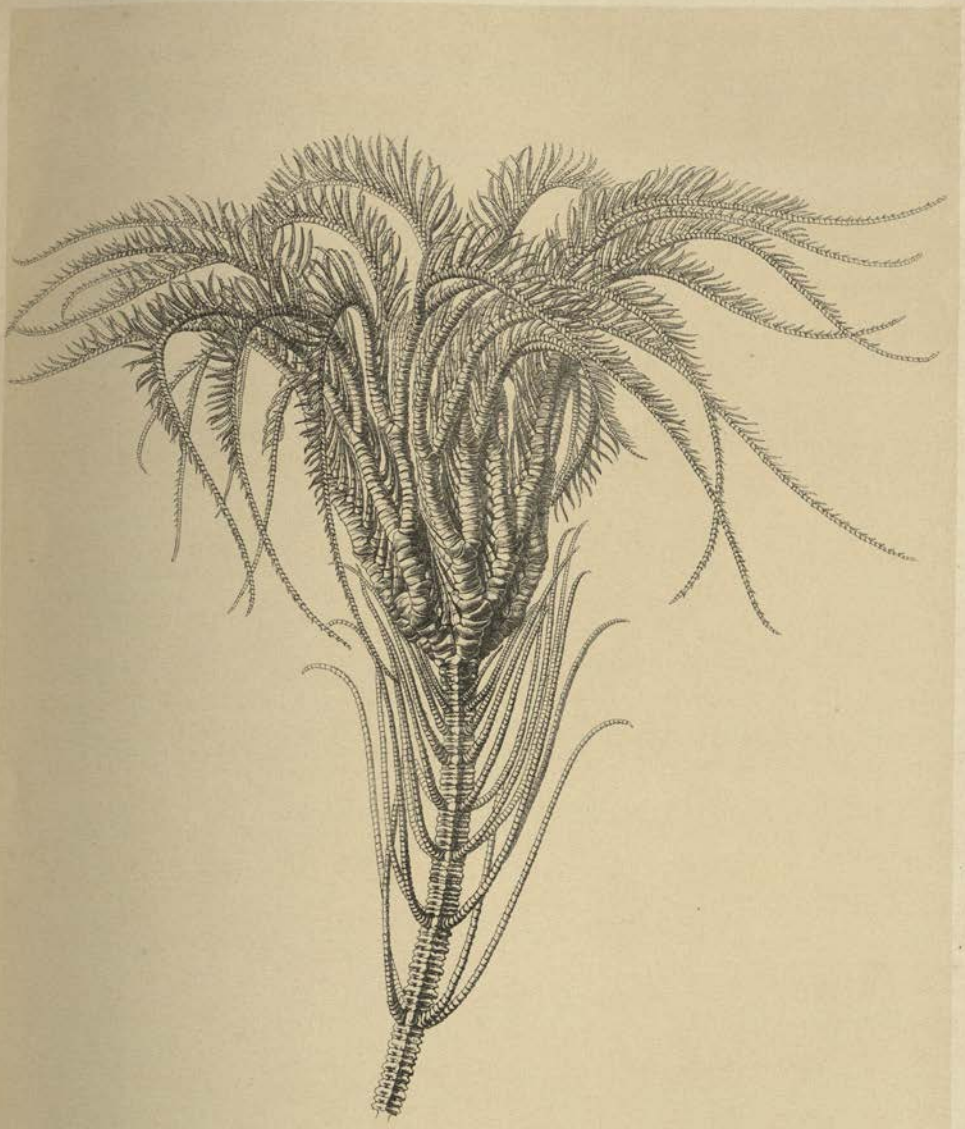
Hanhart imp.

PLATE XXXVIII.

PLATE XXXVIII.

METACRINUS ANGULATUS, n. sp.

Natural size, p. 345.



W. J. Hack, del.

F. Huth, Lith.r Edin.r

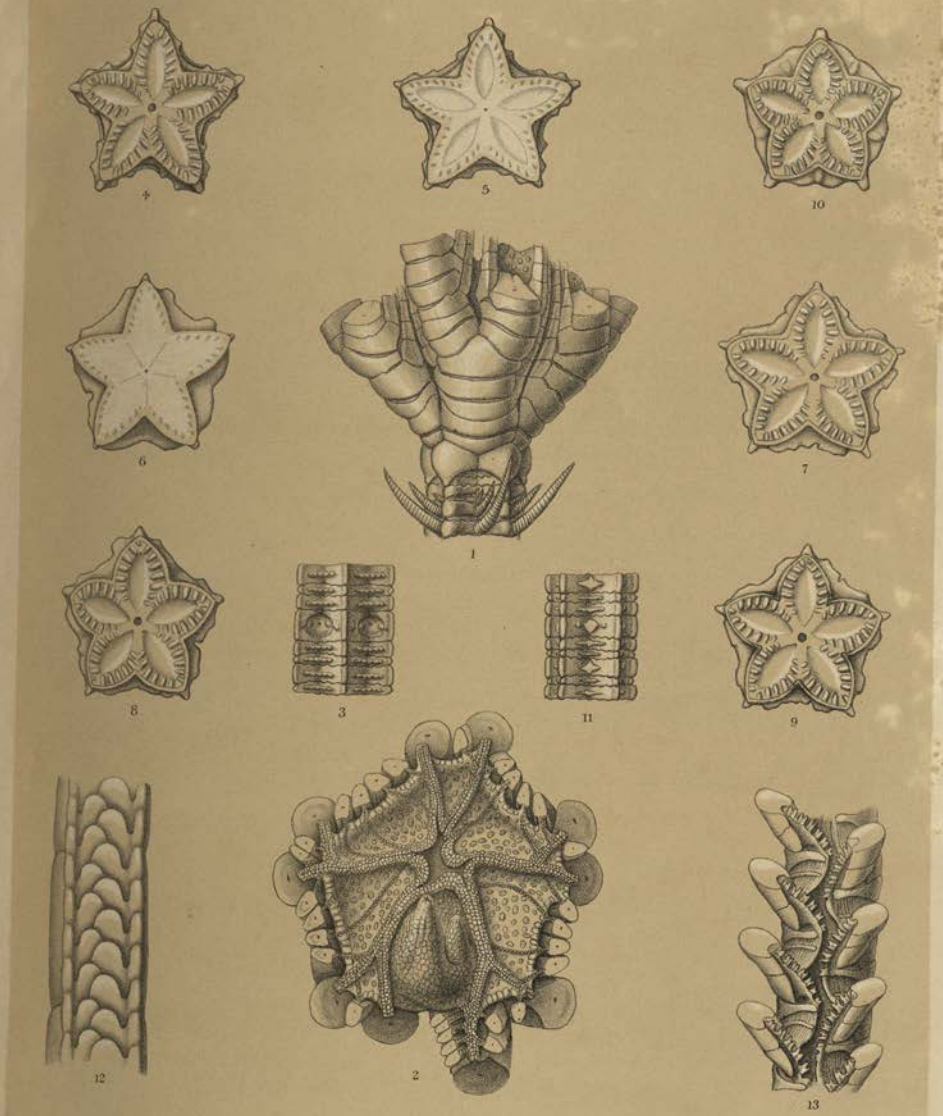
METACRINUS ANGULATUS, Sp. n.

PLATE XXXIX.

PLATE XXXIX.

METACRINUS ANGULATUS, n. sp.

			Diam.	Page
Fig. 1.	The calyx and arm-bases, ...	×	3	341
Fig. 2.	The disk; an abnormal specimen, having a second smaller anal tube by the side of the ordinary one, . . .	×	3	347
Fig. 3.	Portion of the stem, ...	×	3	346
Figs. 4, 5.	Upper and lower faces of a nodal joint, . . .	×	3	13
Figs. 6, 7.	Upper and lower faces of an infra-nodal joint, . .	×	3	13
Fig. 8.	An ordinary internodal joint, ...	×	3	343
Fig. 9.	Lower face of a supra-nodal joint, ...	×	3	343
Fig. 10.	Internodal joint of a varietal form of stem, . . .	×	3	346
Fig. 11.	Side view of a portion of this stem, ...	×	3	346
Fig. 12.	The ambulacral skeleton of a pinnule; from above, . .	×	35	81
Fig. 13.	An arm-groove and brachial ambulacrum, . . .	×	12	81



Benyon & Highley del et lith. P.H.C. dir. Hanhart imp.

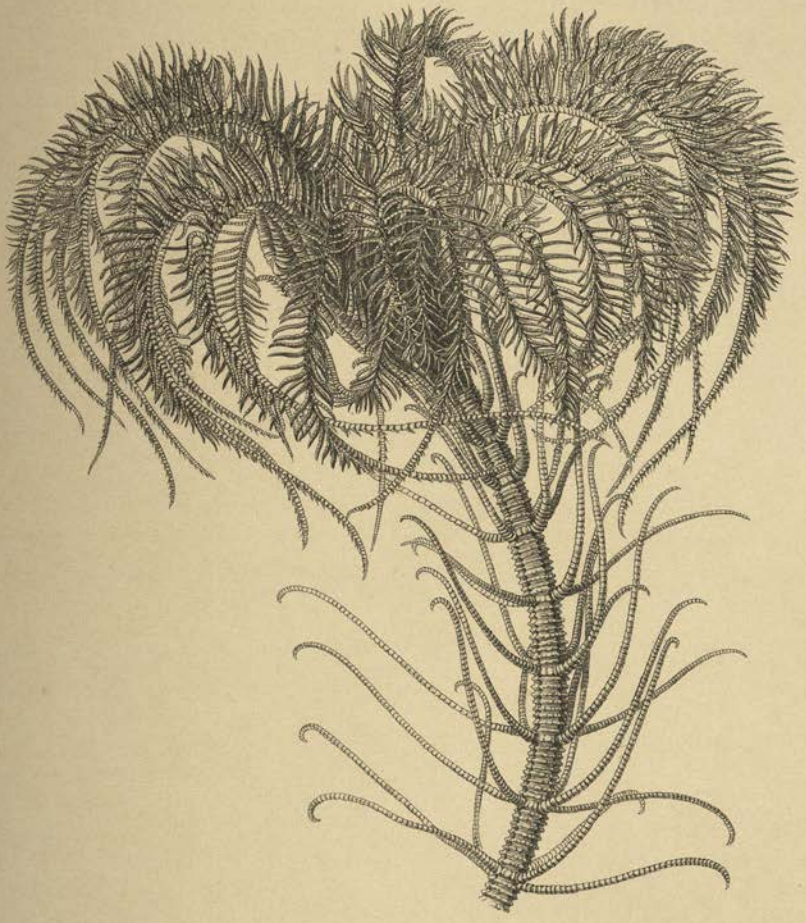
METACRINUS ANGULATUS, Sp.n.

PLATE XL.

PLATE XL.

METACRINUS CINGULATUS, n. sp.

Natural size, p. 347.



W. S. Black, del.

METACRINUS CINGULATUS, Sp. n.

F. Bath, Lith. Edin.

PLATE XLI.

PLATE XLI.

Figs. 1–4. METACRINUS CINGULATUS, n. sp.

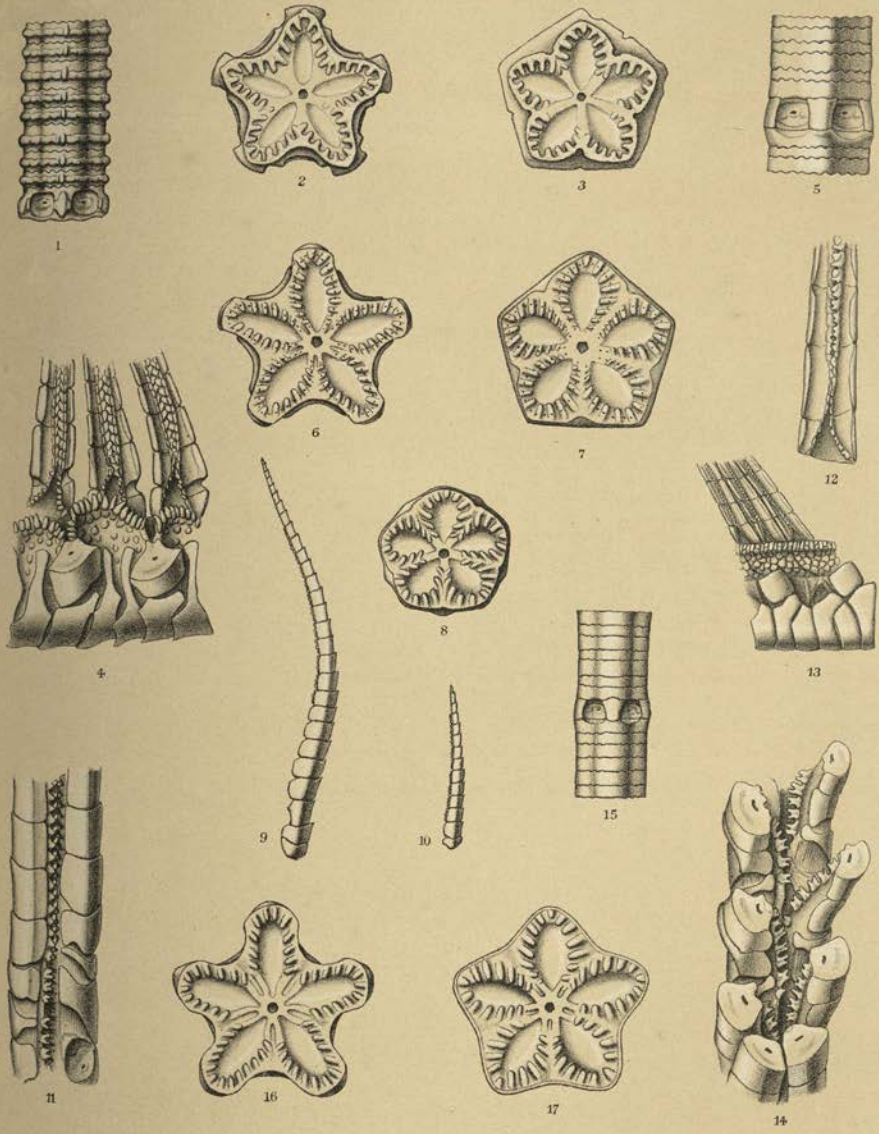
		Diam.	Page
Fig. 1.	Portion of the stem, ...	× 4	348
Fig. 2.	Upper face of a nodal joint, ...	× 7	348
Fig. 3.	An internodal joint, ...	× 7	348
Fig. 4.	Side view of a brachial ambulacrum, ...	× 6	81

Figs. 5–11. METACRINUS NOBILIS, n. sp.

Fig. 5.	Portion of the stem, ...	× 3	352
Fig. 6.	Upper face of a nodal joint, ...	× 5	351
Fig. 7.	An internodal joint, ...	× 5	353
Fig. 8.	An internodal joint of a small specimen, . . .	× 5	353
Fig. 9.	One of the distichal pinnules, ...	× 3	351
Fig. 10.	One of the outer pinnules, ...	× 3	351
Fig. 11.	The arm-groove and brachial ambulacrum, . . .	× 12	82

Figs. 12–17. METACRINUS MURRAYI, n. sp.

Fig. 12.	The lower part of a pinnule-ambulacrum, . . .	× 6	82
Fig. 13.	Side view of a brachial ambulacrum, ...	× 3	81
Fig. 14.	An arm-groove and brachial ambulacrum, . . .	× 12	81
Fig. 15.	Portion of the stem, ...	× 2	351
Fig. 16.	Upper face of a nodal joint, ...	× 5	351
Fig. 17.	An internodal joint, ...	× 5	351



Bergeau & Highley del. et lith.

P.H.C. dir.

Hanhart imp.

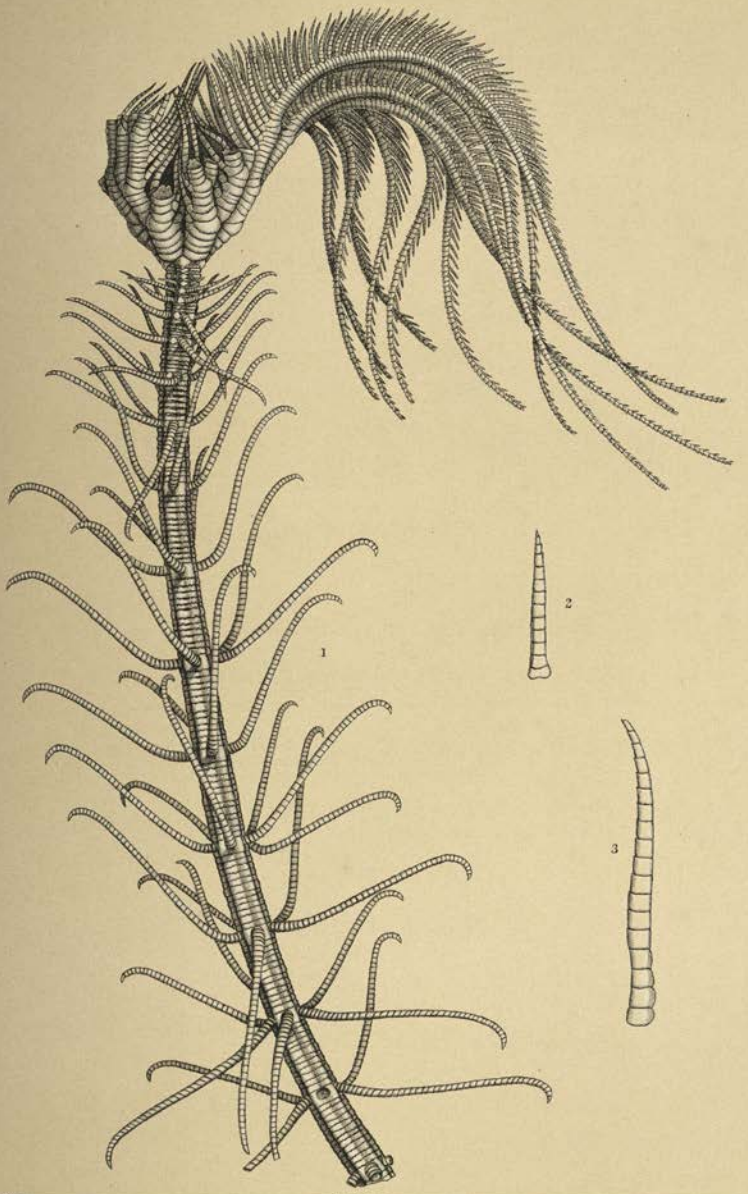
1-4, METACRINUS CINGULATUS, Sp.n. 5-11, METACRINUS NOBILIS, Sp.n.
12-17, METACRINUS MURRAYI, Sp.n.

PLATE XLII.

PLATE XLII.

METACRINUS MURRAYI, n. sp.

	Diam.	Page
Fig. 1. An entire specimen, ...	nat. size	349
Fig. 2. A pinnule from some way out on the free arm, . .	× 3	351
Fig. 3. A pinnule from the fourth arm-division, . . .	× 3	351



Berjeau & Highley del. et lith. P.H.C. chr. Hanhart imp.

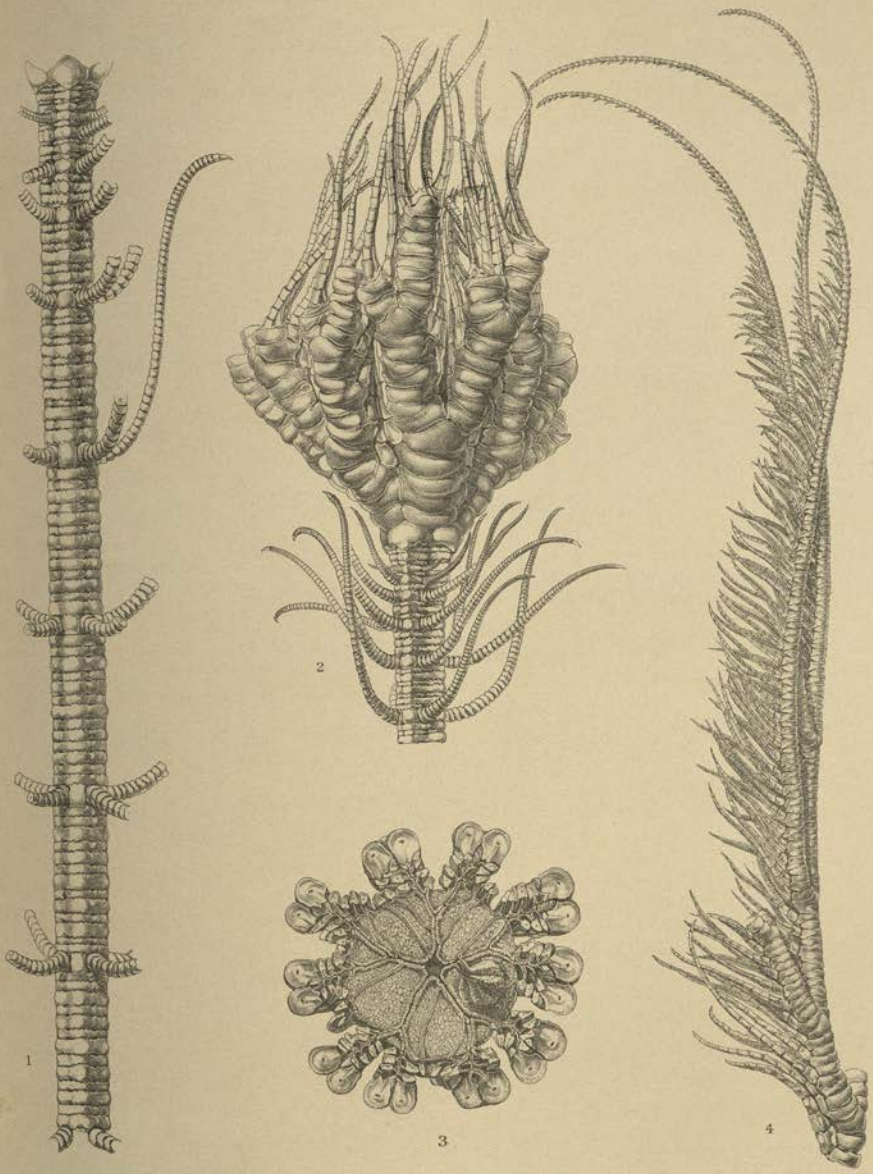
METACRINUS MURRAYI, Sp.n.

PLATE XLIII.

PLATE XLIII.

METACRINUS NOBILIS, n. sp.

		Diam.	Page
Fig. 1. The stem,	×	2	352
Fig. 2. The calyx and arm-bases,	×	2	341
Fig. 3. The disk,	×	2	342
Fig. 4. Portion of a ray,	×	2	341



W. S. Black, del.

F. Bath, Lith^r Edin^r

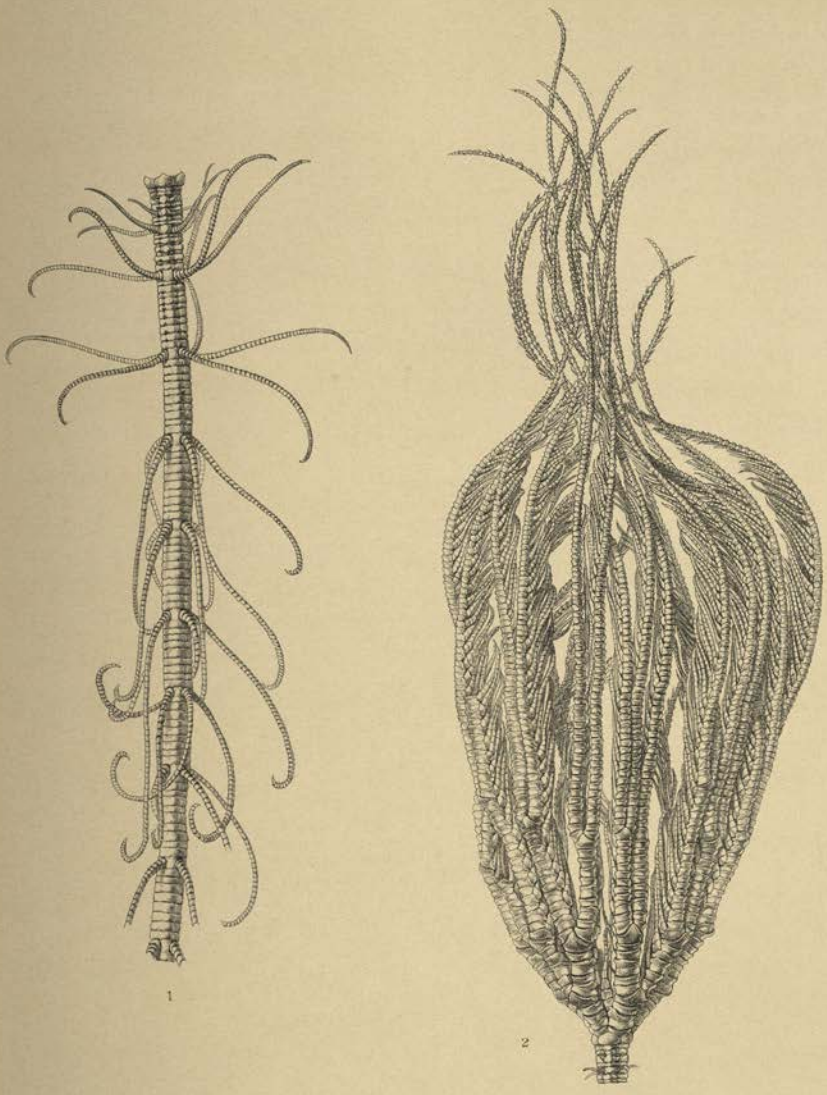
METACRINUS NOBILIS, Sp. n.

PLATE XLIV.

PLATE XLIV.

METACRINUS VARIANS, n. sp.

		Diam.	Page
Fig. 1. The stem,	×	2	342
Fig. 2. The calyx and arms,	×	2	353



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W. S. Black del. F. Huth, Lith^r Edin^r

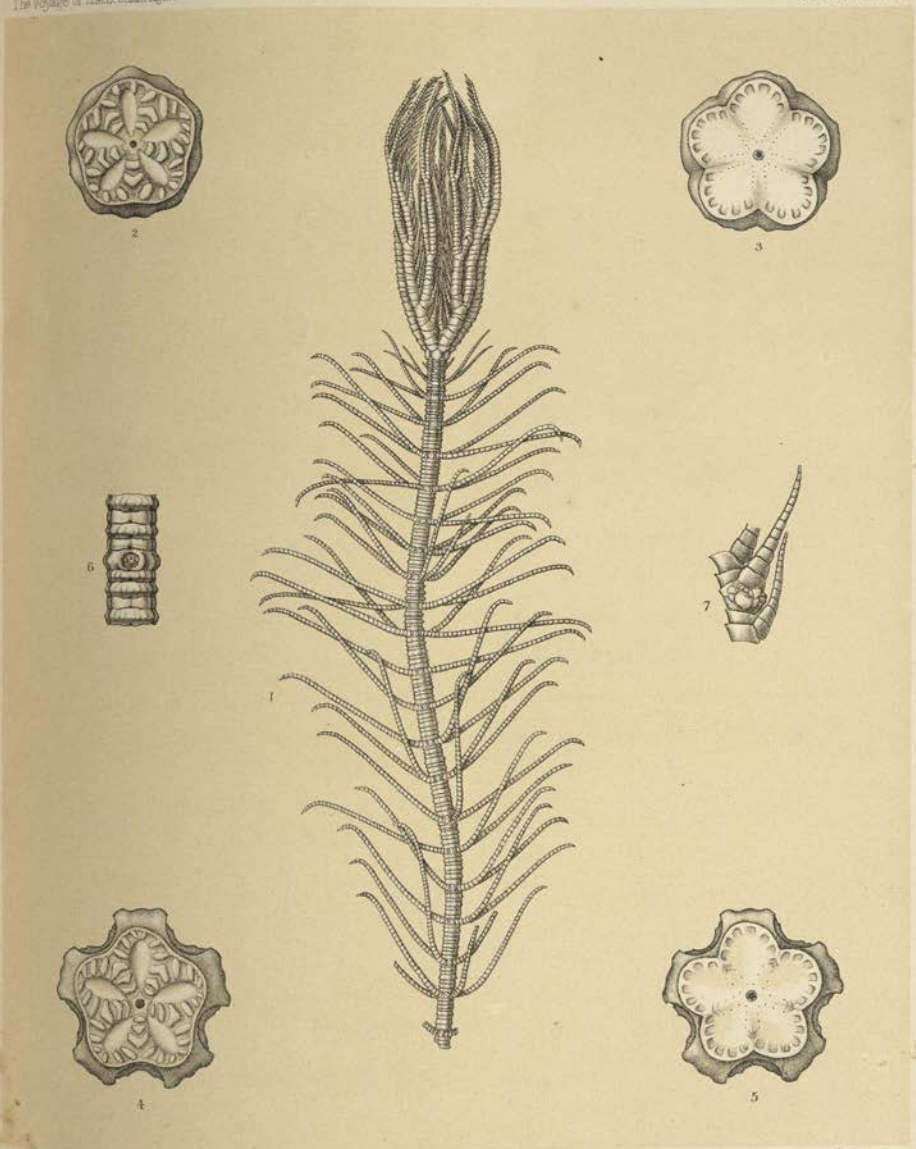
METACRINUS VARIANS, Sp. n.

PLATE XLV.

PLATE XLV.

METACRINUS MOSELEYI, n. sp.

		Diam.	Page
Fig. 1. A young individual,	nat. size		356
Fig. 2. An internodal joint,	×	12	357
Fig. 3. The upper or syzygial face of an infra-nodal joint,	×	12	357
Figs. 4, 5. Upper and lower faces of a nodal joint,	×	12	357
Fig. 6. Portion of the stem,	×	4	357
Fig. 7. Portion of an arm, with commencing *Myzostoma*-cyst,	×	3	358



Berjeau & Highley, del. et lith. P.H.C. dir. Hanhart imp.

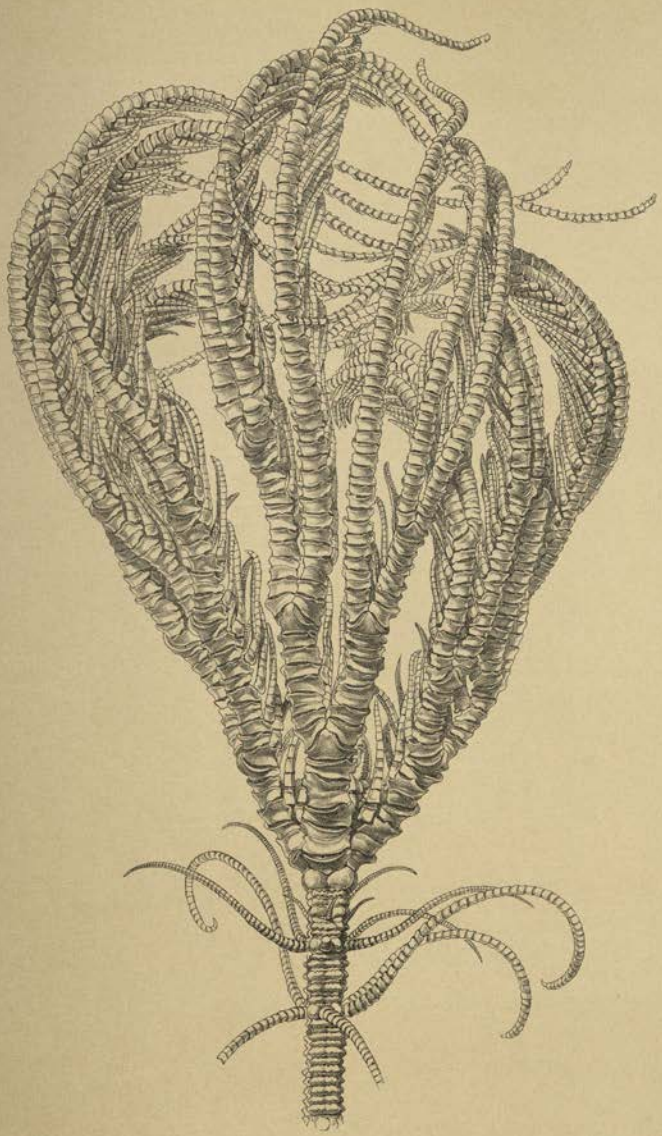
METACRINUS MOSELEYI, Sp. n.

PLATE XLVI.

PLATE XLVI.

METACRINUS MOSELEYI, n. sp.

Diameter $2\frac{1}{4}$ (circa), p. 357.



W. S. Black del.

F. Bath, Lith. Edin.

METACRINUS MOSELEYI, Sp. n.

PLATE XLVII.

PLATE XLVII.

Figs. 1–5. METACRINUS WYVILLII, n. sp.

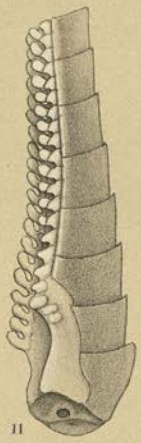
		Diam.	Page
Figs. 1, 2. Portions of the stem, ...	×	4	359
Figs. 3, 4. Upper and lower faces of an infra-nodal joint, . .	×	9	13
Fig. 5. Upper face of a nodal joint, ...	×	9	13

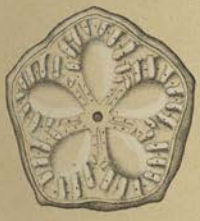
Figs. 6–9. METACRINUS VARIANS, n. sp.

Fig. 6. Portion of the stem, commencing with an infra-nodal joint, and inverted, ...	×	3	355
Figs. 7, 8. Lower and upper faces of a supra-nodal joint, . .	×	8	343
Fig. 9. Upper face of a nodal joint, ...	×	8	13
Fig. 10. The end of a pinnule; from above, ...	×	14	55
Fig. 11. The lower part of a pinnule; from the side, . . .	×	15	82
Fig. 12. The arm-groove and brachial ambulacrum, . . .	×	10	82

Fig. 13. METACRINUS COSTATUS, n. sp.

Fig. 13. The lower part of the ambulacrum of a middle pinnule, .	×	10	364





Berjeau & Highley del. et lith. P.H.C. dir. Hanhart. imp.

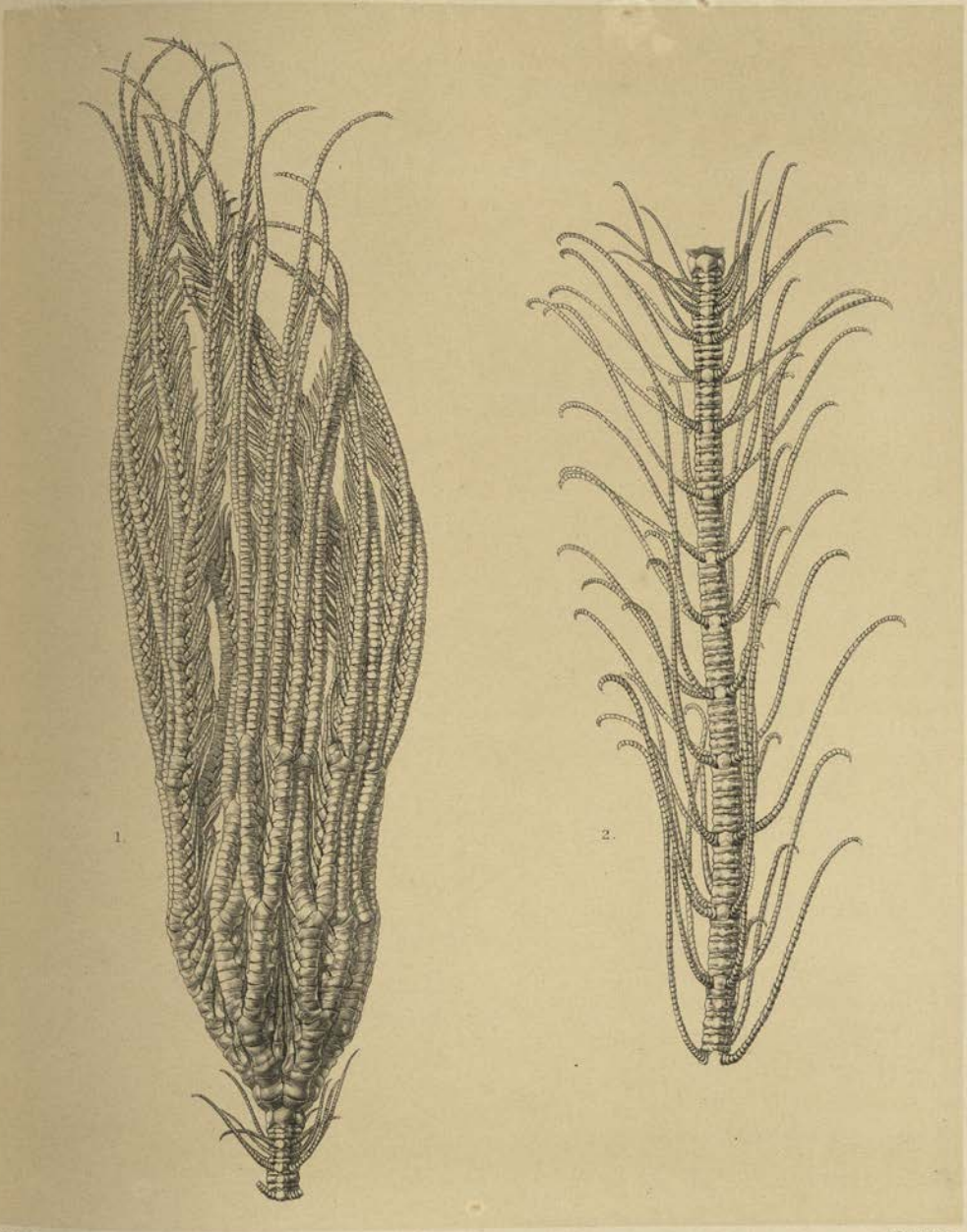
1-5. METACRINUS WYVILLII, Sp.n. 6-12. METACRINUS VARIANS, Sp.n.
13. METACRINUS COSTATUS, Sp.n.

PLATE XLVIII.

PLATE XLVIII.

METACRINUS WYVILLII, n. sp.

		Diam.	Page
Fig. 1.	The calyx and arms, ... ×	$1\frac{1}{2}$ (circa)	358
Fig. 2.	The stem, ... ×	$1\frac{1}{4}$ (circa)	342



W. S. Black, del.

F. Huth, lith^r Edin^r

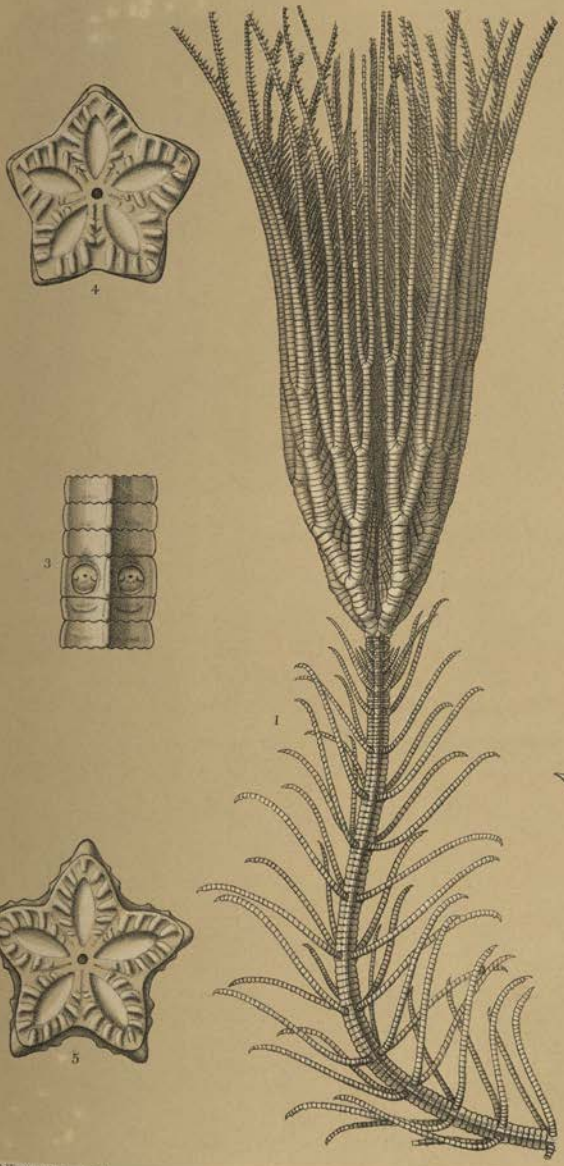
METACRINUS WYVILLII, Sp. n.

PLATE XLIX.

PLATE XLIX.

METACRINUS COSTATUS, n. sp.

			Diam.	Page
Fig. 1.	An entire specimen, ...	nat.	size	360
Fig. 2.	The calyx of an individual in which basals are absent, . .	×	2	363
Fig. 3.	Portion of the stem, ...	×	5	362
Fig. 4.	An internodal joint, ...	×	4	362
Fig. 5.	Upper face of a nodal joint, ...	×	4	362
Fig. 6.	The lower portion of one of the outer pinnules; from the side,	×	15	364
Fig. 7.	The ambulacral skeleton of one of the lower pinnules; from above, ...	×	15	364



Berjeau & Highley del. et lith.

P.H.C. dir.

Hanhart imp.

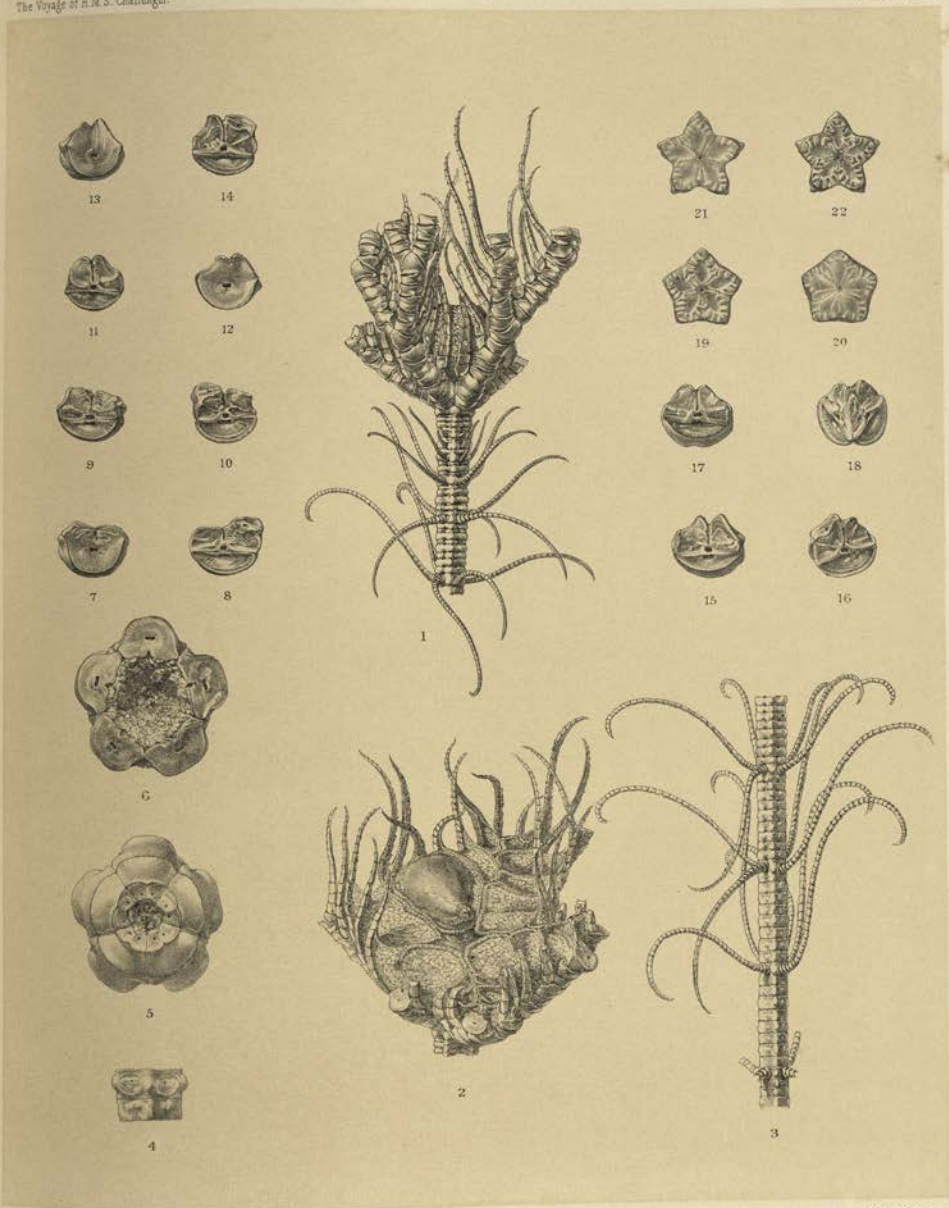
METACRINUS COSTATUS, *Sp. n.*

PLATE L.

PLATE L.

METACRINUS NODOSUS, n. sp.

			Diam.	Page
Fig. 1.	The calyx and arm-bases,	×	2	364
Fig. 2.	Oblique view of the disk from its anterior end,	×	3 (circa)	81
Fig. 3.	Portion of the stem,	×	2	364
Fig. 4.	Nodal and infra-nodal joint of the stem; from the side,	×	4	366
Fig. 5.	The first radials, with the hypozygals of the second, as seen from beneath after removal of the basals,	All × 3 approximately.		293
Fig. 6.	The same; from above,			51
Figs. 7, 8.	Proximal and distal faces of the epizygal of the second radial,			51
Figs. 9, 10.	Proximal and distal faces of the third radial,			51
Figs. 11, 12.	Proximal and distal faces of the hypozygal of the fourth radial,			51
Figs. 13, 14.	Proximal and distal faces of the epizygal of the fourth radial,			51 51
Figs. 15, 16.	Proximal and distal faces of the fifth radial,			51
Figs. 17, 18.	Proximal and distal faces of the sixth or axillary radial,			10
Figs. 19, 20.	Lower and upper faces of an infra-nodal joint,	×	5	13
Figs. 21, 22.	Lower and upper faces of a nodal joint,	×	5	13



W. S. Black del.

F. Huth, Lith. Edin.

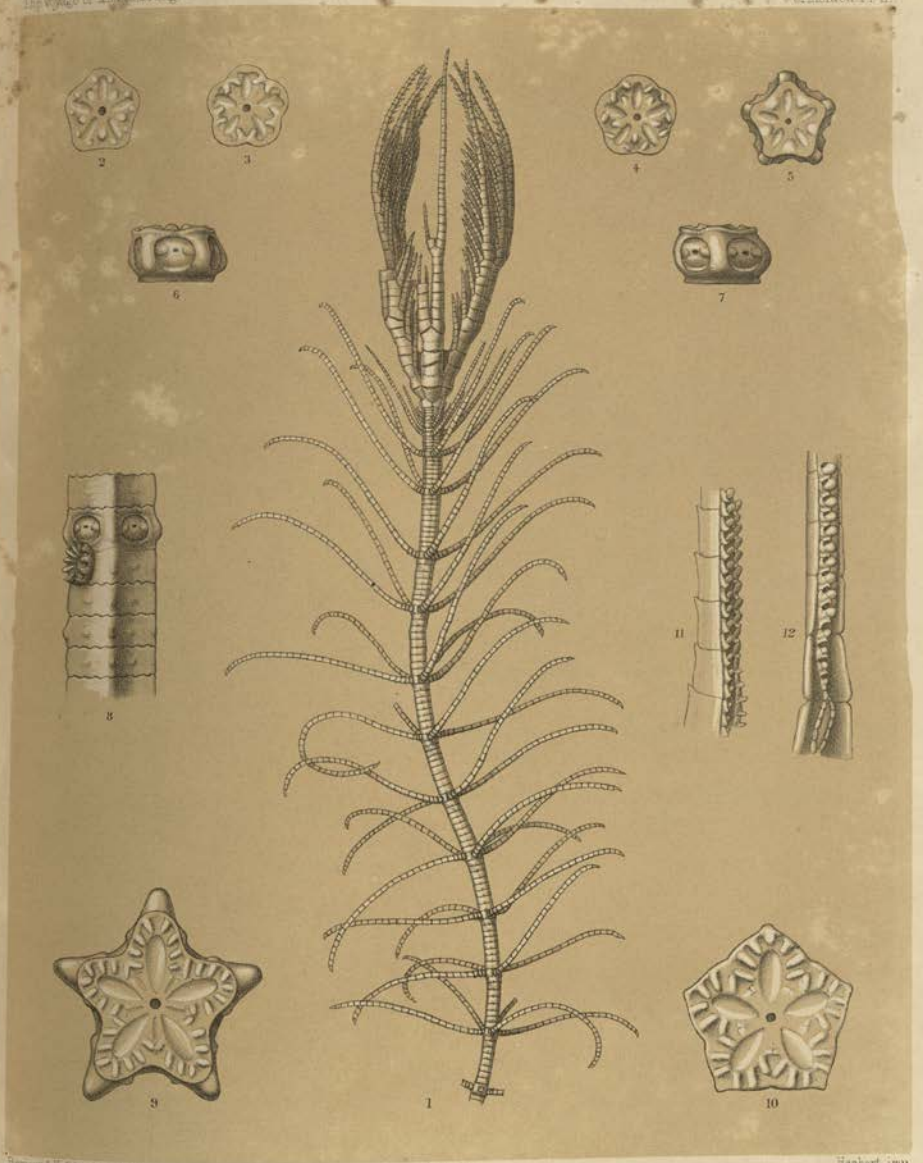
METACRINUS NODOSUS, Sp. n.

PLATE LI.

PLATE LI.

METACRINUS NODOSUS, n. sp.

		Diam.	Page
Fig. 1. A young specimen, ...	nat. size		366
Figs. 2–4. Faces of young internodal joints, ...	×	14	291
Fig. 5. The upper face of a young nodal joint, . . .	×	14	291
Figs. 6, 7. Radial and interradial views of a young nodal joint, .	×	14	366
Fig. 8. Portion of the stem, bearing a young coral, . . .	×	6	367
Fig. 9. Upper face of a nodal joint, ...	×	10	13
Fig. 10. Face of an internodal joint, ...	×	10	368
Fig. 11. Side view of the middle portion of a pinnule, . .	×	15	366
Fig. 12. The lower part of a pinnule-ambulacrum; from above, .	×	15	366



Bergeon & Higgley del. et lith. P.H.C. dir. Hanhart imp.

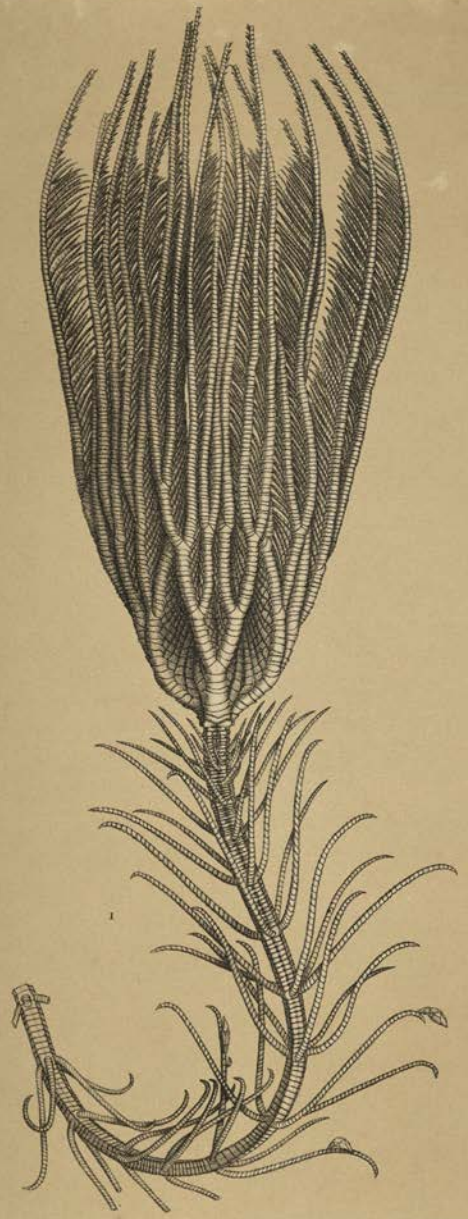
METACRINUS NODOSUS. Sp. n.

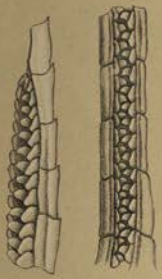
PLATE LII.

PLATE LII.

METACRINUS INTERRUPTUS, n. sp.

		Diam.	Page
Fig. 1. An entire specimen, ...	nat. size		367
Fig. 2. Portion of the stem, ...	×	4	343
Fig. 3. Face of an internodal joint, ...	×	9	368
N.B.—The sides of this joint are somewhat more hollowed than is usually the case.			
Fig. 4. Upper face of a nodal joint, ...	×	9	368
Fig. 5. The termination of the ambulacrum on one of the small outer pinnules; from the side, ...	×	10	55
Fig. 6. Upper view of the ambulacral skeleton nearer the base of the pinnule, ...	×	10	367





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Benjeau & Highley del. et lith.

P.H.C. dir.

Hanhart imp.

METACRINUS INTERRUPTUS, Sp. n.

PLATE LIII.

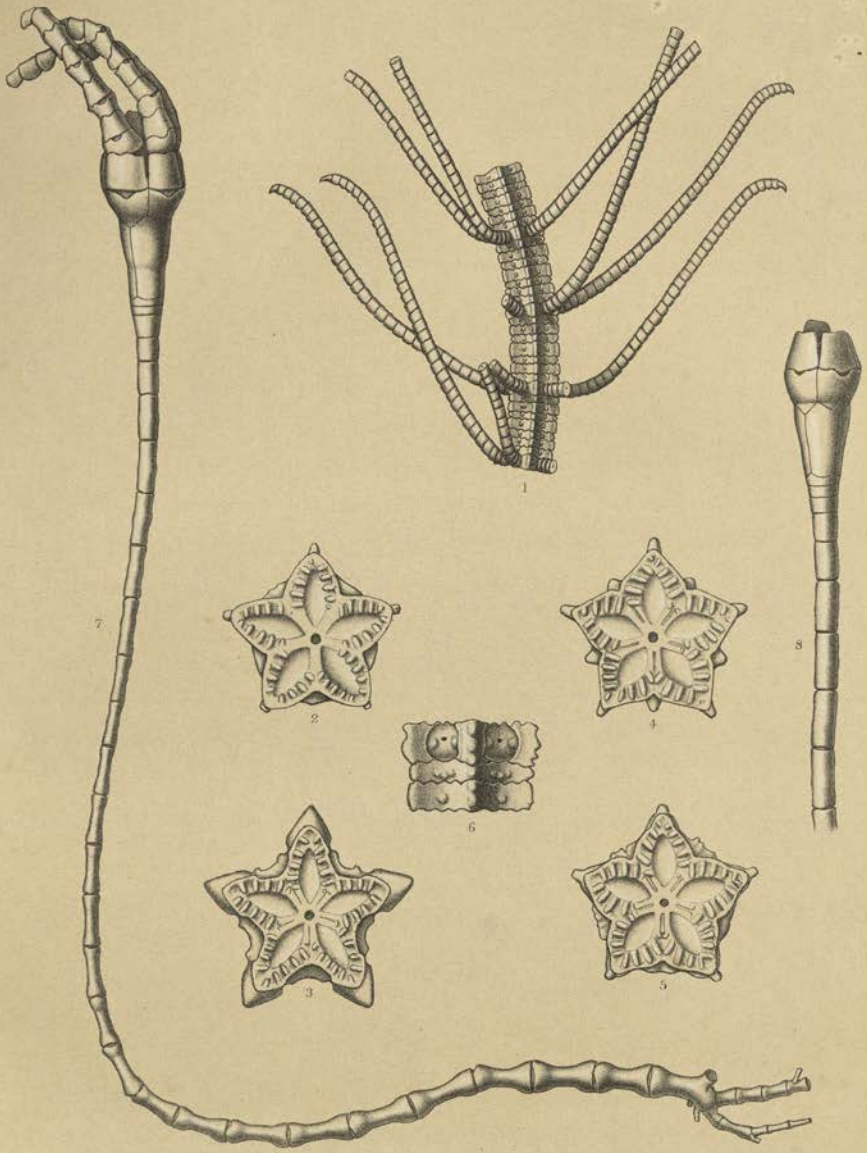
PLATE LIII.

Figs. 1–6. METACRINUS TUBEROSUS, n. sp.

		Diam.	Page
Fig. 1. Portion of the stem, ...	×	2	369
Fig. 2. Lower face of a supra-nodal joint, ...	×	9	370
Fig. 3. Upper face of a nodal joint, ...	×	9	369
Fig. 4. An ordinary internodal joint, ...	×	9	369
Fig. 5. Lower face of an infra-nodal joint, ...	×	9	370
Fig. 6. Side view of a nodal joint and the two upper joints of the internode below it, ...	×	6	369

Figs. 7, 8. RHIZOCRINUS RAWSONI, Pourtalès.

Fig. 7. A young specimen with the arm-bases slightly displaced at the syzygy between the first and second brachials, . .	×	20	265
Fig. 8. The upper part of the stem, with the calyx and first brachials of a slightly older individual, ...	×	20	266



Berjeau & Highley del. et lith. P.H.C. dir. Hanhart imp.

1-6. METACRINUS TUBEROSUS, Sp. n.
7, 8. RHIZOCRINUS RAWSONI, Pourtalès.

PLATE LIV.

PLATE LIV.

Figs. 1–4. ANTEDON ACŒLA, n. sp.

			Diam.	Page
Fig. 1.	Ventral aspect of a portion of an arm from its lower third, .	×	7	83
Fig. 2.	Side view of one of the genital pinnules, . . .	×	10	83
Fig. 3.	The ventral surface of another genital pinnule, . .	×	10	83
Fig. 4.	The ambulacral skeleton of a later pinnule with the covering plates closed down, ...	×	20	83

Fig. 5. ANTEDON ANGUSTICALYX, n. sp.

Fig. 5.	The ventral aspect of an ungrooved genital pinnule, . .	×	13	83

Figs. 6, 7. ANTEDON INCERTA, n. sp.

Fig. 6.	Side view of a genital pinnule with its ambulacrum, . .	×	13	83
Fig. 7.	The ambulacral skeleton of an arm and the lower parts of the pinnules, ...	×	10	83

Fig. 8. ANTEDON INÆQUALIS, n. sp.

Fig. 8.	The ambulacral skeleton of a pinnule; from the side, . .	×	20	83

Fig. 9. ANTEDON BASICURVA., n. sp.

Fig. 9.	Side view of the ambulacral skeleton of a pinnule mounted in dammar, ...	×	30	83

Figs. 10, 11. ACTINOMETRA STROTA, n. sp.

Fig. 10.	The peristome of a dry disk, with the origins of the ambulacra, ...	×	3	85
Fig. 11.	Vertical section of an ambulacrum of a dry disk, . .	×	12	85

Berjeau & Highley del. et lith. P.H.C. dir. Hanhart imp.

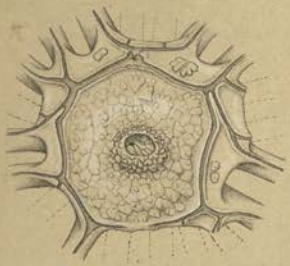
1-4. ANTEDON ACOELA. 5. ANT. ANGUSTICALYX. 6,7. ANT. INCERTA.
8. ANT. INAEQUALIS. 9. ANT. BASICURVA. 10,11. ACTINOMETRA STROTA.

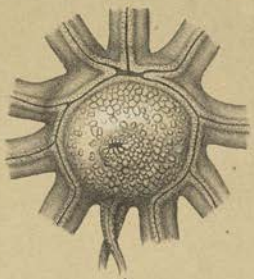
PLATE LV.

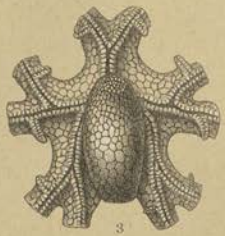
PLATE LV.

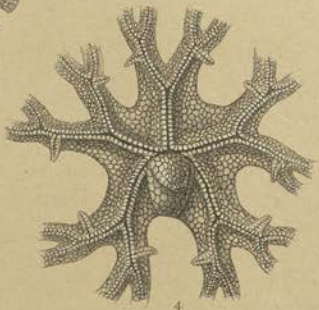
Disks of Comatulæ.

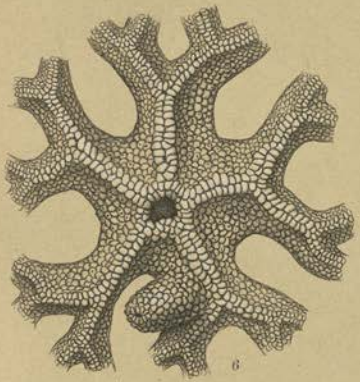
		Diam.	Page
Fig. 1	Disk of *Actinometra jukesi*, n. sp., ... ×	2	85
	A small Isopod is visible within the anal tube (see p. 133).		
Fig. 2.	Disk of *Actinometra strota*, n. sp., ... ×	2	85
	One of the posterior arms is replaced by two pinnules (see p. 60).		
Figs. 3, 4.	Disks of *Antedon multiradiata*, n. sp., . . . ×	4	84
Fig. 5.	Disk of *Antedon acœla*, n. sp., ... ×	10	84
Fig. 6.	Disk of *Antedon angusticalyx*, n. sp., ... ×	10	84
Fig. 7.	Disk of *Antedon basicurva*, n. sp., ... ×	10	84

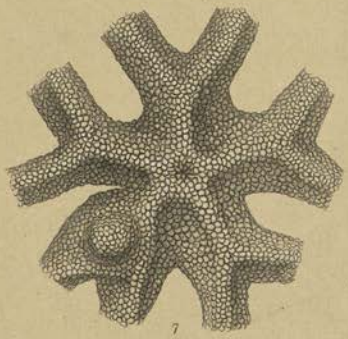












Bergeau & Highley del. et lith. P.H.C. dir. Hanhart. imp.

1. ACTINOMETRA JUKESI, Sp.n. 2. ACTINOMETRA STROTA, Sp.n.
3,4. ANTEDON MULTIRADIATA, Sp.n. 5. ANTEDON ACOELA, Sp.n.
6. ANTEDON ANGUSTICALYX, Sp.n. 7. ANTEDON BASICURVA, Sp.n.

PLATE LVI.

PLATE LVI.

Figs. 1–5. THAUMATOCRINUS RENOVATUS, P. H. Carpenter.

			Diam.	Page
Figs. 1, 2.	Side views, radial. In fig. 1 the right anterior, and in fig. 2 the right posterior ray faces the observer, . .	×	15	371
Fig. 3.	Side view, interradial, ...	×	15	371
Fig. 4.	The anal side, ...	×	15	371
Fig. 5.	The disk, ...	×	15	372

Fig. 6. ANTEDON ROSACEA, Linck, sp.

Fig. 6.	An abnormal disk with two mouths, ...	×	5	70

Fig. 7. ACTINOMETRA MAGNIFICA, n. sp.

Fig. 7.	The disk of the only specimen known, . . .	nat. size		56

The course of the water-vessel which supplies the arms of the posterior ray is marked by a fine line upon the surface of the disk, but it is not accompanied by any food-groove.

Fig. 8. ACTINOMETRA STELLIGERA, n. sp.

Fig. 8.	An abnormal disk with two mouths and two anal tubes, .	×	5	70

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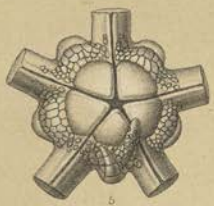
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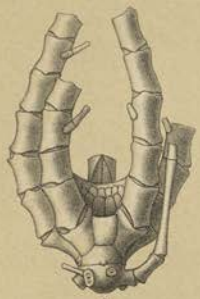
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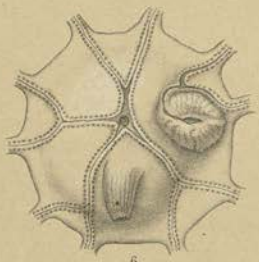
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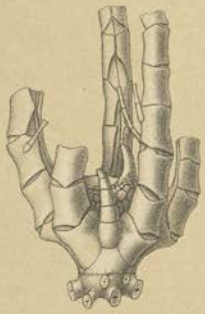
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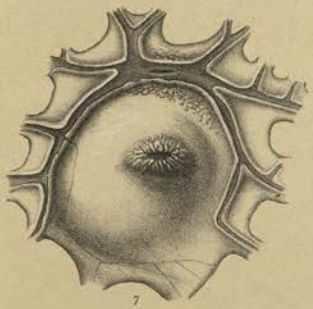
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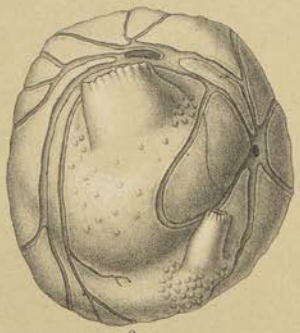
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Berjeau & Highley del. et lith. PHC. dir. Hanhart. imp.

1-5. THAUMATOCRINUS RENOVATUS, Sp.n. 6. ANTEDON ROSACEA, Linck, Sp.
7. ACTINOMETRA MAGNIFICA, Sp.n. 8. ACTINOMETRA STELLIGERA, Sp.n.

PLATE LVII.

PLATE LVII.

The Lettering is the same in all the Figures.

ae. Ambulacral epithelium.
an. Anambulacral plate.
b. Radial blood-vessel.
c. Connective tissue meshwork in the coelom.
cp. Covering plate.
cvc. Circumvisceral coelom.
fg. Fore-gut.
g. Epithelial lining of the gut.
gv. Genital vessel.
ib. Intervisceral blood-vessel.
lp. Labial plexus.
lr. Its radial extensions beneath the ambulacra.
n. Ambulacral nerve.
p. Pigment granules.
re. Rectum.
s. Spinelets on the disk.
sp. Side plate.
sub. Subambulacral plate.
T. Tentacle.
tb. Tentacular branch of water-vessel.
w. Radial water-vessel.
wp. Water-pore.
wt. Water-tube.
x. Plexiform gland.
xv. Its ventral end which joins the labial plexus.

Fig. 1. PENTACRINUS WYVILLE-THOMSONI, Jeffreys.

		Diam.	Page
Fig. 1. Transverse section of the disk in the anal interradius, showing the labial plexus (*lp*) and its extensions beneath the ambulacra (*lr*), ...	×	40	100

Figs. 2-5. PENTACRINUS DECORUS, Wyv. Thoms.

Fig. 2. Vertical section through the outer part of the plexiform gland, showing its connection with the intervisceral blood-vessels,	×	100	101
Fig. 3. The upper part of a longitudinal vertical section through the disk, showing the connection of the labial plexus (*lp*) with the genital and intervisceral vessels (*gv*, *ib*), and also with the ventral end of the plexiform gland (*xv*). The section cuts the edge of the anal tube (*re*), but passes to the right of the mouth, ...	×	30	97
Fig. 4. Transverse section of an ambulacrum near the peristome. This shows the two lateral water-vessels (*w*), which are separated by the radial extension of the labial plexus (*lr*),	×	50	93
Fig. 5. Portion of a vertical section through the periphery of the disk, showing the intervisceral vessels on the outside of the digestive canal, ...	×	100	102

P.H.C. del. Geo. West & Sons del. Lith. et imp.

1. PENTACRINUS WYVILLE-THOMSONI, Jeffreys.
2–5. PENTACRINUS DECORUS, Wyville Thomson.

PLATE LVIII.

PLATE LVIII.

The Lettering is the same in all the Figures.

ai. Primary interradial cords.
ax. The secondary (radial) cords.
B. Basal plate.
c. Bands of connective tissue in the body-cavity.
ch. Cavities of the chambered organ.
ch'. Their downward prolongations into the stem
e. External epithelium.
fg. Fore-gut.
G. Gut.
ib. Intervisceral blood-vessel.
L. Interradial ligament.
l. Basiradial ligament.
lb. Interbasal ligament.
ln. Limestone network in the perisome.
ls. Interarticular ligament of stem.
p. Pigment granules.
R'. First radial.
re. Rectum.
rp. Plug of calcareous tissue within the radial funnel.
V. Central vascular axis of stem.
X. Plexiform gland.

Figs. 1–3. PENTACRINUS DECORUS, Wyv. Thoms.

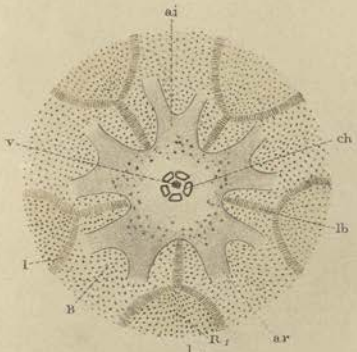
		Diam.	Page
Fig. 1. Horizontal section through the lower part of the calyx, showing the bifurcation of the primary interradial cords (*ai*) in the basals, ...	×	40	124
Fig. 2. Horizontal section through the lower part of the radial pentagon, showing the upward extensions of the cavities of the chambered organ (*ch*), ...	×	40	105
Fig. 3. The central part of a median vertical section through the calyx, showing the chambered organ and its connection with the vascular axis of the stem, ...	×	40	104

Fig. 4. PENTACRINUS NARESIANUS, n. sp.

Fig. 4. Portion of a horizontal section of the disk, showing the position of the plexiform gland (*X*) between the fore-gut and the rectum, ...	×	30	101

Figs. 5, 6. PROMACHOCRINUS KERGUELENSIS, n. sp.

Fig. 5. Portion of a horizontal section of the disk, showing the plexiform gland (*X*), ...	×	35	101
Fig. 6. A similar section nearer the calyx, ...	×	35	101



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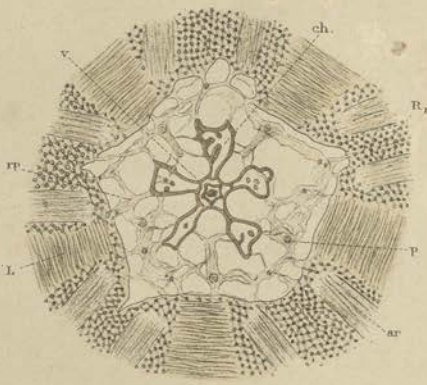

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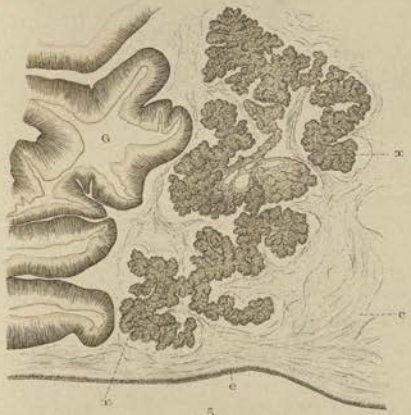

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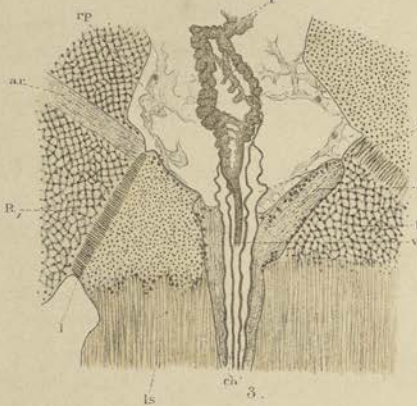

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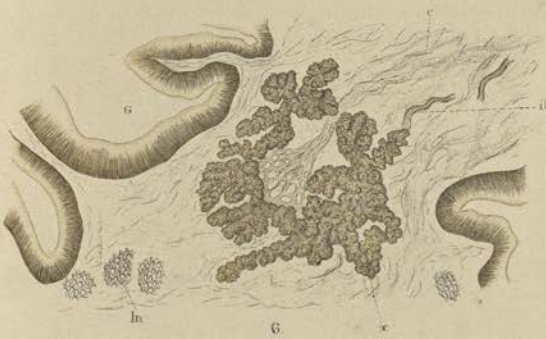

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1–3. PENTACRINUS DECORUS, Wyv. Th. 4. PENTACRINUS NARESIANUS, Sp. n.
5, 6. PROMACHOCRINUS KERGUELENSIS, Sp. n.

PLATE LIX.

PLATE LIX.

The Lettering is the same in all the Figures.

ac. Connective tissue fibres between the anambulacral plates.
ad. The parambulacral extensions of the axial cords into the ventral perisome.
ae. Ambulacral epithelium.
b. Radial blood-vessel.
c. Bands of connective tissue in the body-cavity.
cp. Covering plate.
cvv. Circumvisceral coelom.
e. External epithelium.
fg. Fore-gut.
G. Gut.
g. Its epithelial lining.
gv. Genital vessel.
lp. Labial plexus.
n. Ambulacral nerve.
p. Pigment granules.
s. Spinelets on the anambulacral plates of the disk.
sa. Sacculi.
so. Spongy organ.
sp. Side plate.
stc. Subtentacular canal
T. Tentacle.
tb. Tentacular branch of water-vessel.
w. Radial water-vessel.
wp. Water-pore.
wt. Water-tube.
x. Plexiform gland.
xv. Its ventral end which joins the labial plexus.

Figs. 1–4. PENTACRINUS DECORUS, Wyv. Thoms.

		Diam.	Page
Fig. 1. Transverse section of a brachial ambulacrum, . .	×	100	96
Figs. 2–4. Vertical sections of some of the ambulacral plates of the disk, which bears spinelets and are traversed by fibres of the parambulacral nerve-plexus (*ad*), . . .	×	50	124

Fig. 5. ANTEDON ROSACEA, Linck, sp.

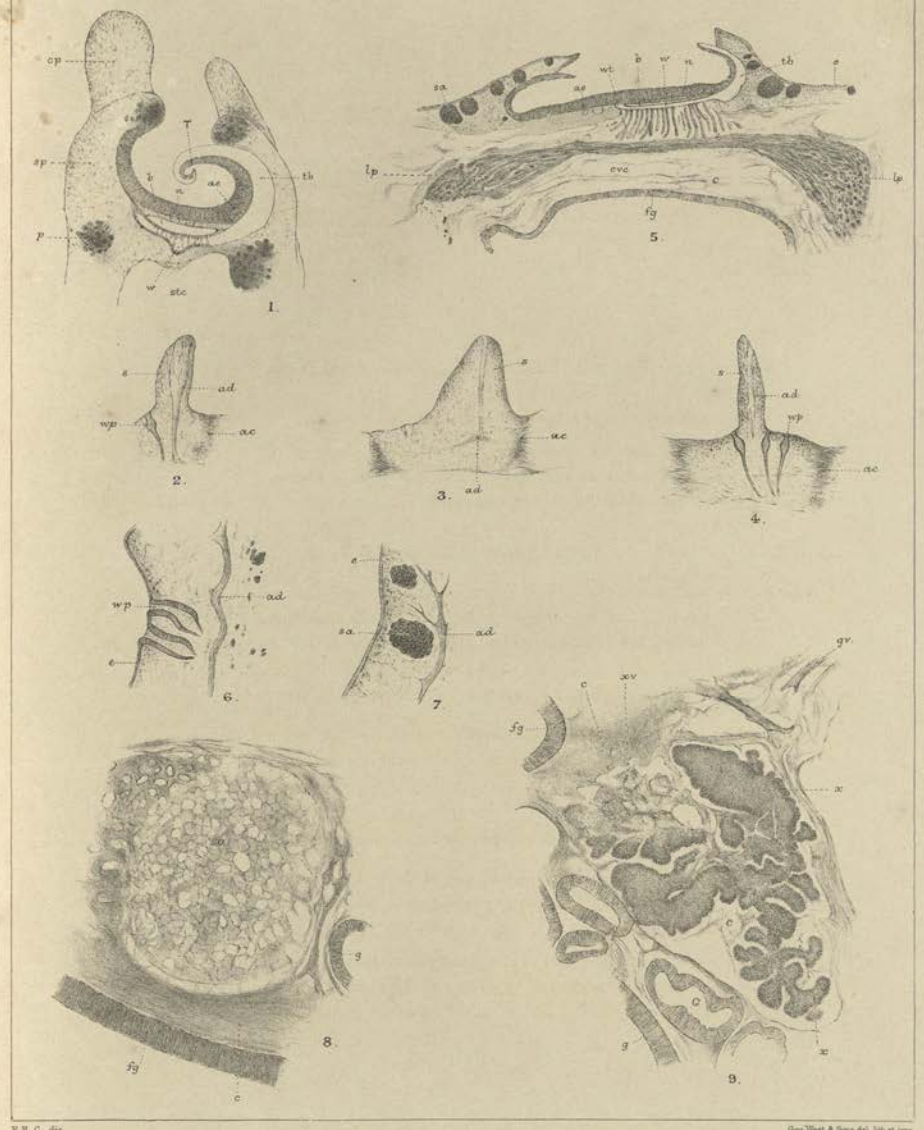
Fig. 5. Vertical section through the left or eastern angle of the peristome, at the origin of the two lateral ambulacra, showing the labial plexus (*lp*) and water-tubes (*wt*), .	×	40	98

Figs. 6, 7. ANTEDON ESCHRICHTI, Müll., sp.

Figs. 6, 7. Portions of vertical sections of the disk in the neighbourhood of an ambulacrum, showing the parambulacral nerves (*ad*), ...	×	100	123

Figs. 8, 9. PROMACHOCRINUS KERGUELENSIS, n. sp.

Fig. 8. Portion of a vertical transverse section of the disk behind the mouth, showing the spongy organ (*so*) at the side of the fore-gut (*fg*), ...	×	40	99
Fig. 9. Portion of another section of the same series, but in front of the mouth, showing the upper end of the plexiform gland (*x*), part of which is becoming reticular and spongy (*xv*),	×	30	99



F. H. C. del. Geo. West & Sons del. lith. et imp.

1–4. PENTACRINUS DECORUS, Wyville Thomson. 5. ANTEDON ROSACEA, Linck. sp.
6, 7. ANTEDON ESCHRICHTI, Müll., sp. 8, 9. PROMACHOCRINUS KERGUELENSIS, Sp. n.

PLATE LX.

PLATE LX.

The Lettering is the same in all the Figures.

a'. Ventral branch of the axial cord of the arm.
ad. The parambulacral extensions of the axial-cords into the ventral perisome of the disk.
ae. Ambulacral epithelium.
b. Radial blood-vessel.
c. Bands of connective tissue in the body-cavity.
cc. Coeliac canal.
cvc. Circumvisceral coelom.
e. External epithelium.
fg. Fore-gut.
g. Epithelium of the gut.
gc. Genital cord.
ge'. Genital canal.
gv. Genital vessel.
ib. Intervisceral blood-vesse
lp. Labial plexus.
n. Ambulacral nerve.
nr. Its oral ring.
p. Pigment granules.
sa. Sacculi.
so. Spongy organ.
stc. Subtentacular canal.
tb. Tentacular branch of water-vessel.
w. Radial water-vessel.
wp. Water-pore.
wt. Water-tube.

Fig. 1. ACTINOMETRA PULCHELLA, Pourtalès, sp.

		Diam.	Page
Fig. 1. Transverse section of an ambulacrum behind the mouth, showing the connection of the genital vessels (*gv*) and labial plexus (*lp*), ...	×	50	98

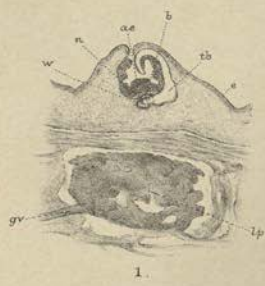
Fig. 2. ANTEDON CARINATA, Leach, sp.

Fig. 2. Portion of a vertical transverse section of the disk in the anal interradius, showing the connection of the genital vessels (*gv*) and labial plexus (*lp*), ...	×	50	98

Figs. 3–6. ANTEDON ESCHRICHTI, Müll., sp.

Fig. 3. Portion of a vertical longitudinal section of the disk, which passes through the peristome, showing the connection of the intervisceral vessels (*ib*) with the spongy organ (*so*), .	×	35	98
Fig. 4. Longitudinal vertical section of the peristome in the direction of a ray, ...	×	60	97
Fig. 5. Part of a vertical transverse section of the disk in the anal interradius, showing the spongy organ and labial plexus, .	×	40	98
Fig. 6. Transverse section of a brachial ambulacrum, showing one of the ventral branches of the axial cord (*a'*)[1] which extend into the perisome at the side of the food-groove, . .	×	65	122

[1] This is wrongly lettered *ad*.



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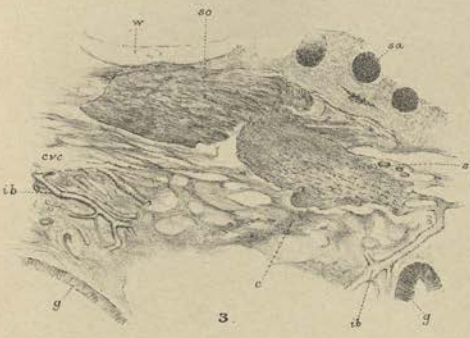

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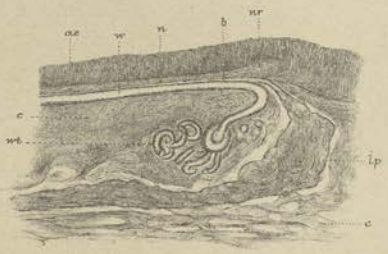

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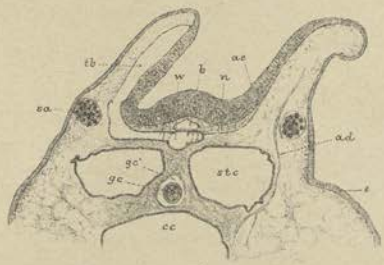


6.

1. ACTINOMETRA PULCHELLA, Pourt., sp.
2. ANTEDON CARINATA, Leach, sp.
3–6. ANTEDON ESCHRICHTI, Müll., sp.

PLATE LXI.

PLATE LXI.

Fig. 1. ACTINOMETRA PULCHELLA, Pourtalès, sp.

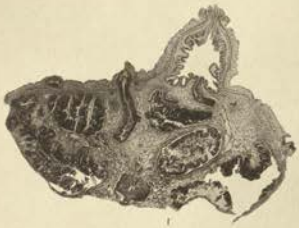
		Diam.	Page
Fig. 1. Vertical longitudinal section of an isolated disk. The section passes through the edge of the mouth, which is seen just in front of the large anal tube. The lobular structure in the centre of the lower part of the disk beneath the fore-gut is the plexiform gland,	×	10	103

Figs. 2–5. ACTINOMETRA PARVICIRRA, Müll., sp.

Fig. 2. Vertical longitudinal section of the calyx and disk. The situation of the chambered organ between the centro-dorsal and radials is well shown; as are also the marginal position of the mouth and the numerous coils of the digestive tube, from some of which the epithelial wall has fallen away. The labial plexus is relatively large in the upper lip (*i.e.*, behind the mouth), but is inconspicuous in front of it,	×	7	103
Fig. 3. Transverse section of an ungrooved or non-tentaculiferous arm, close to the base of a pinnule. The ventral surface is flat, without any food-groove or tentacular apparatus, and owing to the backward extensions of the ovaries below their points of attachment to the genital cord, one appears in section upon each side of the middle line (p. 110),	×	20	113
Fig. 4. The upper part of a transverse section of a normal tentaculiferous arm at the articulation of two joints, showing the connection of the ovary and genital cord. In the coeliac canal is a section of a parasitic worm,	×	25	133
Fig. 5. Transverse section of the lower part of an arm just beyond the attachment of a pinnule. On the left side are seen three funnel-shaped water-pores, the inner ends of which lead into the genital canal containing the triradiate genital cord,	×	27	96

Fig. 6. ACTINOMETRA NIGRA, r. sp.

Fig. 6. Transverse section of an arm through the middle of a joint, showing the branches of its axial cord. The genital canal is occupied by a relatively large genital cord, and the radial blood-vessel is well shown beneath the middle line of the food-groove, between the ambulacral epithelium and the water-vessel,	×	30	121



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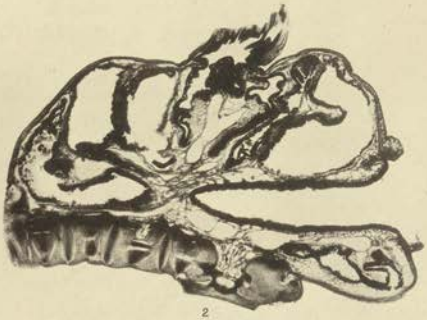

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P.H.C. DIR. AUTOTYPE.

1. ACTINOMETRA PULCHELLA, POURT., SP. 2-5. ACTINOMETRA PARVICIRRA, MULL., SP.
6. ACTINOMETRA NIGRA, SP. N.

PLATE LXII.

PLATE LXII.

Explanation of the Letters.

A. Axial cord of the ray.
a'. Its branches in the dorsal skeleton.
ad. Its upward extensions into the plated perisome of the ventral side.
ae. Ambulacral epithelium.
ai. Primary interradial cords.
an. Anambulacral plate.
B. Basal.
b. Radial blood-vessel.
c. The bands of more or less calcified connective tissue in the body-cavity.
ca. Fibrillar sheath round the vascular axis of the stem.
cco. Interradial portion of the circular commissure.
ch. Cavities of the chambered organ.
ch'. Their downward prolongations into the stem.
chn. The nodal enlargements of these peripheral vessels.
cv. Cirrus-vessel.
D_2, D_5. Second and fifth distichals.
fg. Fore-gut.
G. Gut.
g. Its epithelial lining.
gv. Genital vessel.
iv. Intervisceral blood-vessel.
l. Basiradial ligament.
ld. Dorsal ligament between the ray-joints.
li. Interarticular ligament.
lp. Labial plexus.
M. Mouth.
m. Muscle.
n. Ambulacral nerve.
nr. Its oral ring.
ob. Oral blood-vascular ring.
R_1, R_3. First and third radials.
rc. Rectum.
rp. Plug of calcareous tissue within the radial funnel.
s. Spinelets on the anambulacral plates.
stc. Subtentacular canal.
sub. Subambulacral plate.
sy. Syzygy.
V. Central vascular axis of stem.
W. Radial water-vessel.
wp. Water-pore.
wr. Water-vascular ring.
wt. Water-tube.
x. Plexiform gland.
xv. Its ventral end which joins the labial plexus

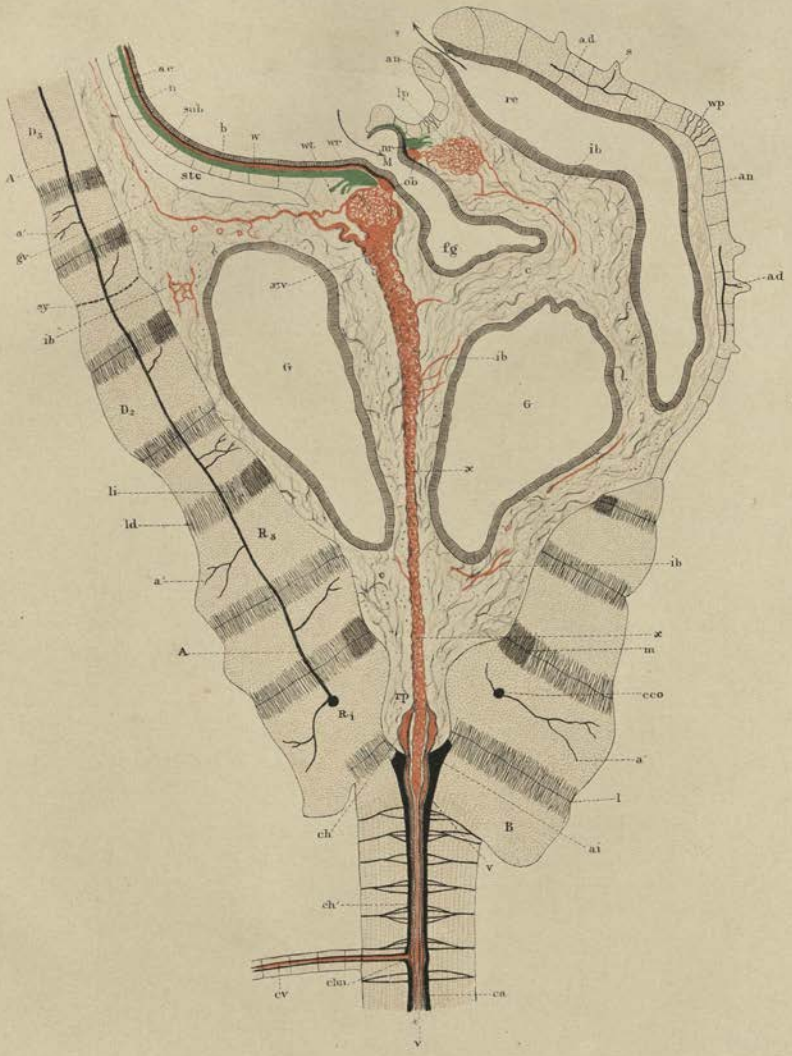
Explanation of the Colours.

Black—The nervous system, both ambulacral and antambulacral.

Green—The water-vascular system.

Red—The blood-vascular system and the plexiform gland.

Diagrammatic longitudinal section of a *Pentacrinus decorus*. On the right side of the figure the section cuts the anal tube, and on the left side it passes along a ray and the base of an arm.



Berjeau & Highley del et lith.

P.H.C. dir.

Mintern. Bros imp.

PENTACRINUS DECORUS, Wyville Thomson.

THE

VOYAGE OF H.M.S. CHALLENGER.

ZOOLOGY.

REPORT on the Isopoda collected by H.M.S. Challenger during the Years 1873-76. By Frank Evers Beddard, M.A. (Oxon.), F.R.S.E., F.R.M.S., F.Z.S., M.B.O.U., Prosector to the Zoological Society of London.

PART I.—THE GENUS SEROLIS.

PREFACE.

Among the Isopoda collected during the Challenger Expedition the genus *Serolis* occupies a very prominent position both as regards number of specimens and of new species; for this reason I have thought it advisable to separate *Serolis* from the rest of the group, which will be treated of in the second part of my Report.

As many as sixteen different species were collected during the voyage, of which nine are new. One of these new species was named *Serolis bromleyana*, and briefly described by the late Dr. von Willemoes Suhm in his Preliminary Report on Crustacea observed during the voyage of H.M.S. Challenger;[1] the remaining eight have already been briefly noticed by myself.[2]

Into the systematic part of this Report I have also introduced some account of the remaining species of the genus that were not obtained by the Challenger in order to make the Report more complete.

The portion which deals with the internal anatomy of *Serolis* is unfortunately very incomplete; the specimens were not very favourably preserved for anatomical investigation, and I did not feel justified in using a great amount of material.

[1] *Proc. Roy. Soc. Lond.*, vol. xxiv. p. 585, 1876.

[2] *Proc. Zool. Soc. Lond.*, pt. iii. p. 330, 1884.

A discussion of the systematic position of the genus *Serolis* within the order Isopoda will be best postponed until after a more detailed study of the remaining part of the collection.

With regard to the alleged affinity of *Serolis* (and of the Isopoda generally) for the extinct Trilobites, insisted upon by Milne-Edwards,[1] I have nothing to add to what has already been said; the examination of the Challenger collection of *Serolis* has brought to light no facts which tend to show any close resemblances between the two groups.

I have to thank Mr. E. J. Miers of the British Museum for kindly facilitating my study of the specimens of *Serolis* preserved in the national collection.

HISTORICAL NOTICE.

The first recorded notice of *Serolis* is contained in Fabricius's Systema Entomologiæ, which was published in 1775. Under the name of *Oniscus paradoxus* is a short description of a species subsequently named *Serolis fabricii* by Leach, and which was obtained at the Straits of Magellan during Captain Cook's second voyage.

A few years later (1767) Fabricius briefly defined this species in his Mantissa Insectorum; in both these works *Oniscus* is placed in the class Synistata, which forms the third class of the four into which Fabricius divided what are known now as Arthropoda, and which included, besides the Isopoda, the majority of the Insecta now classed within the orders Hymenoptera, Diptera, and Heteroptera.

In his Species Insectorum, published in 1781, Fabricius gave another description of this species, still under the name of *Oniscus paradoxus;* here Fabricius hints at the Trilobite affinities of the genus "An protypon Entomolithi paradoxi? In multis certe convenit."

In 1798 appeared Fabricius's Entomologia Systematica, which is a considerable advance upon his earlier works. His eighth class, Polygonata, includes all the Crustaceans belonging to Latreille's order Isopoda as well as the genus *Monoculus;*[2] the name *Oniscus paradoxus* is altered to *Cymothoa paradoxa*, and a fuller definition of the genus is given.

Fabricius's *Cymothoa paradoxa* was first recognised as the type of a new genus by the English naturalist Dr. W. E. Leach; in the twelfth volume of the Dictionnaire des Sciences Naturelles, published in the year 1818, is an article by Leach on the Cymothoadæ, where *Cymothoa paradoxa* is redescribed under the name of *Serolis fabricii*.

In 1825 Desmarest in his Considerations generales sur les Crustacés recapitulated Leach's description of *Serolis fabricii*. Both Desmarest and Leach denied the supposed affinities of *Serolis* with the Trilobites.

In 1833 James Eights described in the Transactions of the Albany Institute, vol. ii.

[1] *Arch. d. Mus.*, t. ii. p. 5; *Ann. d. Sci. Nat.*, sér. 6, t. xii. art. No. 3.

[2] *Monoculus* includes all the members of the order Entomostraca.

p. 53, pls. i. and ii., another species of *Serolis* under the name of *Brongniartia trilobitoides*, which name was subsequently altered by Audouin and Milne-Edwards into *Serolis trilobitoides*, since there was evidently no generic difference from *Serolis paradoxa*; this paper contains merely a description of the new form, accompanied by figures in which the whole animal as well as the mouth appendages and the two first abdominal limbs are displayed; a figure of a Trilobite, *Paradoxus boltoni*, is given for the purpose of comparison, but there is no account in the text of any supposed resemblances between the two forms, except the similarity of the eyes. It seems not unlikely that this species is identical with Studer's *Serolis cornuta*, or at most a local variety. This species was obtained on the coast of Patagonia from the stomach of a fish belonging to the genus *Phycis*, and also from the South Shetlands.

The next contribution is a paper by Audouin and Milne-Edwards, which was published in the Archives du Muséum for 1841. This important memoir on the genus *Serolis* contains, after an historical introduction in which all the previous notices regarding the genus are reviewed, a general account of its external characters, and a description of four species—*Serolis paradoxa*, *Serolis trilobitoides*, *Serolis orbignyi*, and *Serolis gaudichaudii*, the two last being here described for the first time; the memoir is illustrated by figures of these species and of all the essential parts in their anatomy; with regard to the affinities of the genus, it is considered as intermediate between the other Isopoda and the Trilobites. Several of these figures are repeated in the magnificent illustrated edition of Cuvier's Regne Animale, edited by his disciples Audouin, Milne-Edwards, Latreille, &c., though the text of this work appears only to contain a description of *Serolis paradoxa*.

The Histoire Naturelle des Crustacés of Milne-Edwards, published in 1840, contains a description of the genus *Serolis* and of the four species *Serolis fabricii* (=*Serolis paradoxa*), *Serolis brongniartiana* (=*Serolis trilobitoides*), *Serolis orbigniana*, and *Serolis gaudichaudii*; in this work *Serolis* is included in the family Cymothoadæ, which is divided into three tribes—(1) Cymothoadiens ravisseurs, *Serolis*; (2) Cymothoadiens errans, *Ægа*, *Conilera*, &c.; (3) Cymothoadiens parasites, *Cymothoa*, *Nerocila*, &c.

In 1852 Dana described a new species of *Serolis* (*Serolis planus*) in the Crustacea of the United States Exploring Expedition.

Six years later (1858) another species was described by Lütken, to which he gave the name of *Serolis schythei*.

The next and a most important contribution to our knowledge of *Serolis* is Grube's Monograph of the genus, published in 1875. Besides the description of a new species (*Serolis tuberculata*), a general résumé of the external characters of the genus, and some notes on certain species (*Serolis paradoxa* and *Serolis schythei*) that had been previously described, are to be found in this paper, together with a complete list of the then known species, eight in number. Grube regards *Serolis* as being most nearly allied to *Sphæroma*.

During the "Transit of Venus" Expedition to Kerguelen in 1875, two species of *Serolis* were obtained, which were figured and described by Miers, one of these—*Serolis septemcarinata*—being new.

About the same time the German ship "Gazelle" collected a number of species of *Serolis* both at Kerguelen and on the shores of South America, which were described by Studer[1] in 1879. This paper contains, besides the description of a new species (*Serolis cornuta*), a few notes upon the habits of these animals and upon some points in their anatomy.

A few notes upon certain of the species of *Serolis* that are described in the present Report are to be found in v. Willemoes Suhm's Preliminary Report upon the Crustacea collected during the voyage of the Challenger.[2]

Finally, a recently published part of Bronn's Thierreichs (Bd. v. Abth. 2, Heft i.–x.) contains a general account of the Isopoda by Prof. A. Gerstaecker, where some description of the genus *Serolis*, especially of the geographical distribution, is given; there are also in this work a number of figures copied from the Memoirs of Grube and Studer; and a comparative view of the various schemes of classification of the order Isopoda; for this reason I have not in the present Report entered into any account of the systematic positions which have been assigned to the genus *Serolis* by previous writers.

[1] *Archiv f. Naturgesch.*, Jahrg. xlv. Bd. i. p. 104.
[2] *Proc. Roy. Soc. Lond.*, vol. xxiv. p. 585, &c., 1876.

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DESCRIPTION OF THE GENUS.

Serolis, Leach.

Oniscus, Fabricius, Mantissa Insectorum, p. 240, 1787. In Part.
Asellus, Olivier, Encycl. Méth., t. i. p. 252. In Part.
Cymothoa, Fabricius, Entomol. Syst., ii. p. 503, 1793. In Part.
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Definition.—Body much depressed, round or oval in form, usually furnished with long sickle-shaped epimera. Cephalic shield broad, terminating anteriorly in a short median rostrum, uniting with first two segments of thorax to form a cephalothorax. Terminal segment of thorax rudimentary, its tergum unrepresented; sternum partially fused with that of preceding segment; epimera absent. Abdomen consisting of three free segments and a caudal shield; first segment devoid of epimera, and completely enclosed by the preceding and succeeding segments; second and third segments with longer or shorter epimera. Caudal shield usually pentagonal, with one or more longitudinal carinæ, rarely smooth. First pair of antennæ subequal in length to second pair, the former with four basal joints and a multiarticulate flagellum, the latter with five basal joints and a multiarticulate flagellum. Mandibles stout and strong, with a long three-jointed palp. Maxillæ small and delicate. Maxillipedes large and operculiform, entirely covering maxillæ. Ambulatory appendages seven pairs; anterior pair (in male second pair also) modified into a prehensile organ, the terminal joint folding back upon the greatly dilated penultimate joint; last thoracic appendage smaller than the others; first three pairs of abdominal appendages natatory, with broad basal and two expanded distal joints fringed with long plumose hairs; inner joint of second pair prolonged in the male into a penial filament; fourth and fifth appendages branchial; sixth pair natatory, comparatively small.

External Characters.—The depressed form of the body which characterises the family of the Isopoda as contrasted with the Amphipoda is very marked in the genus *Serolis;* in some species (*Serolis schythei, Serolis cornuta,* &c.) the body is almost flat; in others again (*Serolis convexa,* &c.) the convexity of the dorsal surface is greater, and *Serolis*

latifrons is conspicuous by its strongly arched dorsal surface, which, together with the shortness of the epimera, causes this species to resemble in general aspect the more typical forms of the Cymothoadæ.

The outline of the body varies from oval (*Serolis tuberculosa*) or even pear-shaped (*Serolis convexa*) to circular, and in the males of *Serolis schythei* and *Serolis cornuta* the diameter of the body from side to side is somewhat greater than the length.

In the majority of the Isopoda the "head" segments become fused with the first segment of the thorax, and form a cephalic shield which is freely movable upon the second thoracic segment. In *Serolis* the disposition of the anterior segments of the body differs much from other Isopoda. The first two thoracic segments are closely united and completely fused dorsally, though the sterna of the two remain distinct; in some species (*Serolis schythei, Serolis neæra,* &c.) an incomplete transverse suture upon the first epimera seems to mark the line of division between the two segments dorsally; in others again (*Serolis antarctica* and all the Australian species) the epimera of the two thoracic segments are completely united, and show no traces of their original distinctness; these epimera are always largely developed, and completely enclose the cephalic shield on both sides. The cephalic shield is very large and has the form of an heraldic shield; it is prolonged in front into a short rostrum; its shape varies considerably in the different species, in some (*Serolis neæra, Serolis paradoxa*) the antero-lateral portions are considerably expanded, and the transverse diameter is greatest here and decreases posteriorly; in other species (*Serolis convexa, Serolis schythei*) the cephalic shield is widest at the level of the eyes. In the majority of species the cephalic shield is separated from the two thoracic segments by a continuous suture; in *Serolis longicaudata* this suture is obsolete behind and indicates the commencement of the formation of a cephalothorax composed of the head segments and the two first thoracic segments as in *Tanais*, with which genus *Serolis* is considered by some to be closely connected. The five following thoracic segments are free; the eighth or terminal segment of the thorax differs from that of other Isopoda in being only represented ventrally by a short sternum, which is more or less intimately fused with that of the preceding segment, and is not prolonged into epimera; the tergum of this segment is entirely undeveloped, and the rudimentary condition of the whole segment (including the appendages, which are much smaller than those of the other thoracic segments) is interesting, inasmuch as in the Isopoda generally the terminal segment of the thorax is only developed very late.

The epimera of the thoracic segments are almost always largely developed in comparison with other Isopoda; and in some of the deep-sea species (*Serolis bromleyana, Serolis neæra*) are extraordinarily elongated, and terminate in sharp spiniform points. As a general rule the epimera are flat and sickle-shaped, curving back and gradually increasing in length up to the sixth pair, which are invariably the longest; sometimes (*Serolis latifrons, Serolis longicaudata,* &c.) the epimera are very short, and hardly exceed

in length those of many Cymothoadæ; where the epimera are only moderately developed they are in close contact for the greater part of their length, the anterior slightly overlapping the posterior; in *Serolis neœra*, *Serolis bromleyana*, and *Serolis gracilis* the epimera are quite independent for the greater part of their length, and are only in actual contact for a short space close to the junction of the epimera and tergum; at this point the anterior margin of the epimeron projects forwards as a short rounded process which is received into a "glenoid" cavity between two similar processes, one dorsal and one ventral, of the epimeron in front; of these processes only traces exist in *Serolis schythei* and those species in which the epimera are closely applied to each other; an intermediate condition is seen in *Serolis paradoxa* and other species, where each epimeron has two articular processes, one anterior and one posterior; the anterior process of each segment overlaps the posterior process of the segment in front.

The epimera of the first three free thoracic segments are invariably separated from their terga by a distinct suture; in some species (*Serolis schythei*) the following pair of epimera are also thus separated; in *Serolis latifrons* all the free thoracic segments have the epimera divided by a suture from the terga.

The *abdomen* in *Serolis* consists of three freely movable segments and a terminal caudal shield which represents the three posterior appendages of the abdomen together with the telson.

The anterior segment of the abdomen is enclosed between the penultimate thoracic and the second abdominal segment, and in one species only has any traces of epimera; in *Serolis latifrons* a minute portion is separated off from the median portion on either side by a suture; and as this suture is quite continuous with those in front which separate the terga and sterna of the thoracic segments, it seems that the minute nodule on either side of the first abdominal segment really represents its epimeron. The two succeeding segments are always furnished with epimera, which are, however, never separated by a suture from the terga, and in most cases are short and not prolonged beyond the lateral margin of the caudal shield; in some species, notably in *Serolis bromleyana*, the epimera of these segments are elongated, and reach midway down the margin of the caudal shield, or even considerably beyond its termination.

The remaining abdominal segments are fused with the telson to form a caudal shield which is commonly more or less pentagonal in outline, and is always furnished with a longitudinal carina and sometimes with a pair of lateral carinæ which appear to mark the line of division between the posterior abdominal segment and the telson; the greater portion of the caudal shield is occupied by the latter.

Appendages.—The two pairs of *antennæ* are generally subequal in size, sometimes (*e.g.*, *Serolis minuta*) the anterior pair, sometimes (*e.g.*, *Serolis cornuta*) the posterior pair are the longer.

The anterior antennæ consist of four joints and a terminal filament, while the posterior

antennæ have a stem composed of five separate joints; the terminal filament is usually shorter than that of the anterior antennæ.

Tactile Organs.—The peculiarly modified antennary hairs first described by Leydig,[1] and believed by him to be sense organs, exist upon the first pair of antennæ only in all the species of *Serolis* that I have examined. These organs are of two kinds, the most conspicuous being cylindrical jointed hairs, several of which are displayed in Pl. I. fig. 4, *b*; each consists of a basal portion somewhat hour-glass shaped, which is attached to the inner side of the upper extremity of each of the joints which compose the filament of the antennules; this is continued into a delicate cylinder with thin walls, which is always divided into two portions by a transverse septum, and occasionally seems to consist of three distinctly separated portions; the distal end of each of these cylinders is formed by a knob-like thickening of the chitinous wall. Leydig describes and figures nerve fibres and cells in these olfactory hairs, but the Challenger specimens were not sufficiently well preserved to show these structures.

As a general rule, only one of these olfactory hairs is found upon each joint of the antennulary filament, but in *Serolis antarctica*, *Serolis australiensis*, and one or two other species, two such hairs are found upon each joint.

The "tactile" organs described by Leydig in the Memoirs already quoted I have only seen in *Serolis schythei* and *Serolis neœra;* on the antennules of these two species one tactile hair only is found upon the distal extremity of the terminal point (Pl. V. fig. 5, *a*); it is a short slender hair, the upper half being plumose. Similar hairs are also found over the general body-surface and upon the first joint of the ambulatory appendages (Pl. III. fig. 11) of many species.

The *mandibles* are very strong and powerful, and furnished with a long three-jointed palp which is longer than the mandible itself; the second joint of the palp is longer than the first joint, and the third, which is very small, is semicircular in shape, and its flat inner margin is furnished with a row of stiff hairs, of which the two distal ones are the longest. These hairs are continued for a short way on to the middle joint of the palp, this part of the joint being of a somewhat greater diameter than the posterior portion, which is devoid of hairs. The basal portion of the mandible is broadest proximally, where it articulates with the head, it narrows abruptly into the distal half, which is not more than one half of its diameter; the latter is bent at an angle to the basal part, terminates in the masticatory edge which is of a dark brown colour, and is either straight or slightly sinuous, or provided with one or two blunt tooth-like projections; in adult specimens only are the mandibles thus furnished with a comparatively smooth edge, which appears simply to be due to wear and tear; in young specimens of all the species

[1] Fr. Leydig, Ueber Geruchs- und Gehörorgane der Krebse und Insecten, *Archiv f. Anat. u. Physiol.*, 1860, pp. 265–314, Tafn. vii.–ix. See also the same Ueber Amphipoden und Isopoden, *Zeitschr. f. wiss. Zool.*, Bd. xxx., Supplement, pp. 225–274, Taf. ix.–xii., 1878.

that I was able to examine the inner edge of the mandibles is strongly toothed. Schiödte, in a memoir upon the structure of the mouth in the Isopoda,[1] has figured and described the mouth parts of *Serolis paradoxa;* the mandibles are distinguished from those of other Isopoda by their blunt edge, which renders them especially fitted for grinding and not for tearing, and Schiödte suggests that the food of *Serolis* probably consists of "such animals as have firm integuments;" in all the specimens that I have examined the stomach contained debris of other Crustacea, frequently recognisable fragments of their own species, besides Diatoms, morsels of the calcareous structure of Echinodermata, &c.; Schiödte is therefore quite right in his supposition regarding the food of *Serolis*, and is no doubt justified in distinguishing this genus from other Isopoda by the characters of its mouth appendages.

The mandibles of *Serolis*, however, possess additional cutting blades and spiniform processes which appear to have been overlooked or imperfectly described and figured by all previous writers with the exception of Schiödte. On Pl. II. figs. 2, 3 are figured the distal extremity of both mandibles right and left of *Serolis latifrons;* the left mandible has upon the upper surface a triangular chisel-like blade, and below this a long spine; the right mandible has the spine, but the cutting blade is smaller. The left mandible of other species is quite similar to that of *Serolis latifrons*, but as a general rule (*cf. e.g.*, fig. of *Serolis schythei*, Pl. II. figs. 12, 13) the cutting blade is not present on the right mandible, its place being occupied by a large spine-like structure. The presence of these structures appears to me to fit the mandibles for tearing as well as grinding.

The asymmetry of the mandibles is marked not only by the differences just mentioned but also by the general shape of the masticatory edge (*cf. e.g.*, Pl. II. figs. 12, 13) and by the fact that one mandible, generally the left, is smaller than the other. An asymmetry of the mandibles appears to be a fairly constant character of the Isopoda.

The *maxillæ* are small and delicate; the anterior pair consist of a narrow basal portion or "cardo," with which is articulated a long flat somewhat curved distal lobe; the free edge of this is furnished with a considerable number of strong spines dark yellow in colour. In some species (*e.g.*, *Serolis pallida*) the lobe of the maxilla is much more bent upon itself and proportionately shorter. In many species I have observed an additional lobe, which is situated below the large masticatory lamina articulating with the cardo (see Pl. V. fig. 14); the presence of this was noticed by Audouin and Milne-Edwards, but subsequently denied by Grube.[2]

The second pair of maxillæ are smaller and more delicate than the anterior pair, but like them consist of a basal portion or "cardo" and a distal portion, which is divided into two lobes, the upper of which is again subdivided; the two anterior are subequal and smaller than the posterior lobe, which is separated by a distinct suture; the free extremities of all bear a number of hairs more delicate than those on the first maxillæ,

[1] *Kröyer, Nat. Hist. Tidsskr.*, ser. 3, vol. iv. (1866); translated in *Ann. and Mag. Nat. Hist.*, ser. 4, vol. i. p. 1 *et seq.*

[2] *Archiv f. Naturgesch.*, Jahrg. xii. Bd. i. p. 214.

and pinnate at their extremity. There are generally two upon each of the smaller anterior lobes and a greater number upon the posterior lobe; in a specimen of *Serolis cornuta* (*cf.* Pl. I. figs. 9, 10) this pair of maxillæ, like the mandibles, was asymmetrical on one side; each of the two smaller lobes had two long hairs upon its free extremity; on the side one of the smaller lobes was markedly larger than the other, and furnished with four hairs instead of two.

In *Serolis convexa* the second pair of maxillæ differ in that all the three lobes are approximately of equal size, and all bear a considerable number of hairs (Pl. VI. fig. 14).

The *maxillipedes* are of considerable size and entirely conceal the subjacent maxillæ; they are closely approximated in the middle line; each consists of a squarish basal portion and a palp; the basal portion is divided by a transverse suture into two, and each of these is again divided by a longitudinal suture; the proximal half or cardo articulates with both the median (sphenoidal plate) and the lateral portion of the sternum. The outer half of the distal half or "stipes," which is generally, though not always, completely separated from the inner "lamina" by a suture, is thin and flat; the lamina is stout, and usually furnished on the inner margin with a row of fine hairs; the upper end invariably bears two thick spines; the palp of the maxilla, which consists of three joints, the middle one the longest, is attached to the lamina about three-quarters of the way down; the second and third joints of the palp are furnished with long hairs on the inner side in all species; the other joints of the maxillipede are sometimes smooth, sometimes furnished with long hairs, according to the species.

The *second thoracic appendage* (*cf.* Pl. VI. fig. 10) is modified into a prehensile organ, the penultimate joint is large and swollen, and the terminal joint is recurved and lies along its inner margin like the blade of a penknife when closed; the inner margin of the penultimate joint has a number of peculiarly formed spines, unlike any that are found elsewhere on the body. Of these there are two kinds which regularly alternate; one set (Pl. VIII. fig. 15) consist of a central stem terminating above in a knob,[1] the margins are beset with a number of fine branches which are fused together on each side for the greater part of their length; the other kind of spines (Pl. VIII. fig. 14) which alternate with these, and are placed slightly more on the ventral side, are long and delicate, expanding above into two processes, one of which is frequently longer and somewhat spoon-shaped, between these the central axis of the spine terminates in an oval knob; the shape of these hairs varies much in the different species, and will be more fully described below under the several species.

The fourth joint of this appendage, which is sometimes (*Serolis tuberculata*) prolonged into a forwardly directed triangular process, is always furnished with two spines, and has in the males of *Serolis convexa* and *Serolis gaudichaudii* a tuft of sensory hairs (see p. 17).

The *third pair of thoracic appendages* in the male (see p. 16) is modified into a

[1] Owing to an error in the plate, this is represented as a forked process.

prehensile organ like the preceding limb, but smaller. In the female it is similar to the succeeding appendages.

The *remaining thoracic appendages* are similar to each other, and are always furnished with tufts of hairs and spines. The first joint, which is always the longest, is generally smooth, or provided on the inner surface with fine plumose hairs like the single sensory hair commonly found upon the terminal point of the filament of the first antennæ. The four following joints are smaller, and generally furnished on the inner and outer side with tufts of sword-like and of serrated spines. In many species (*Serolis antarctica*) these are to a great extent replaced by fine hairs, and in *Serolis neœra* all the thoracic appendages are clothed with fine plumose hairs similar to those which in other species are only to be found upon the abdominal appendages. A more detailed description of the varieties of these hairs and spines will be found under the description of the several species.[1]

The last pair of thoracic appendages (see p. 17) are usually smaller, and very often in the males (*Serolis gracilis*) furnished on the inner side with tufts of delicate sensory hairs like those upon the second thoracic appendage in the males of *Serolis convexa*.

The *abdominal appendages* (see Pl. I. figs. 12–14) are much specialised; the three anterior pairs form "swimming feet"; each of these consists of a proximal joint, the protopodite, which is generally triangular in form and attached to the segment which bears it for about a quarter of the length of the base; the projecting angle bears *three* plumose hairs in the first of these appendages and *two* in each of the two following. In some species (viz., *Serolis schythei*, *Serolis paradoxa*, and in all the Australian species), the protopodite is narrower, less triangular in form, and has *no* hairs. The inner margin is usually clothed with a dense covering of fine delicate hairs, which are also found, though to a less extent, upon the outer border. About half-way between the summit and the base the endopodite is attached, and the exopodite at the summit of the protopodite; both the exopodite and endopodite are delicate semicircular lamellæ, the former being larger than the latter; the outer convex margin of both is provided with numerous plumose hairs which, as shown on Pl. I. figs. 15, 16, consist of a central hollow stem gradually decreasing in diameter towards the extremity, and giving off on either side a series of extremely fine lamellæ; in the interior of the stem I was able to observe, in several cases (Pl. I. fig. 16), a fine thread occasionally looped upon itself and possibly a nerve fibre; the function of these hairs may perhaps be to test the quality of the water coming to the gills.

The lower border of the endopodite in the second of these appendages is prolonged in the male into a penial filament (Pl. VII. fig. 2′, *b*). The next two pairs of appendages consist of a short basal joint laterally elongated, with which are articulated two broad lamellæ, an endopodite and exopodite, which are the gills; the exopodite of the first appendage is

[1] I make an arbitrary distinction here and elsewhere between the finer "hairs" and stouter "spines" in order to express more easily the differences between the ambulatory appendages of different species.

much stouter than its endopodite, and forms an "operculum" divided by a transverse suture, which may be at right angles to the longitudinal axis (*Serolis tuberculata*, &c.) or inclined more obliquely to it (*Serolis schythei*, &c.); very commonly (*Serolis neœra*, Pl. V. fig. 11) the endopodite of this appendage is bifid at the tip, the inner branch being prolonged beyond the outer; in most cases, however, the endopodite is entire; the second pair of gills is always smaller than the anterior pair, the exopodite and sometimes the endopodite is divided by a transverse suture which follows the direction of the suture on the exopodite of the first pair of gills. The terminal appendages of the abdomen or "uropoda" are always comparatively small; in *Serolis antarctica* they are extremely minute; these appendages consist of a triangular basal joint attached by the apex to a notch on the lateral margin of the caudal shield, which varies in position in different species, being sometimes at the anterior end of the lateral margin of the caudal shield, sometimes close to its posterior extremity; the inner angle of the protopodite is always longer than the outer, and the endopodite is longer than the exopodite; in *Serolis latifrons* Studer[1] has correctly described the elongated and spine-like endopodite which becomes completely fused with the protopodite, while the exopodite remain very short; the appendage is capable of being flexed at right angles to the body, and its sharp spiniform character doubtless serves as a protection against many foes.

Sexual Characters.—The generative apertures of the male are always situated on the last thoracic segment, on either side of the median ventral line they are always closely approximated, but differ slightly in different species; in some (*e.g.*, *Serolis antarctica*) they are so close together as almost to form a single orifice; in others (*Serolis schythei*, &c.) they are a little further apart.

The female generative apertures are more widely separated from each other than the male generative apertures; they are situated on the antepenultimate thoracic segment, and have the form of an oval slit, while the male generative apertures are invariably circular.

The ova are carried about by the female until the young are fully formed; the immature females have four ovigerous lamellæ (see Pl. V. fig. 4) developed on the second to the fifth thoracic segments inclusive, which are short, oval in shape, and attached close to the attachment of the thoracic limbs. Studer[2] was the first to point out that these lamellæ become much larger in the mature females with eggs, and overlap each other in the middle line, those on the right generally covering those on the left; this disposition of the ovigerous lamellæ, though general, is not, however, universal; occasionally (*e.g.*, *Serolis convexa*) the arrangement of the lamellæ alternates, the right hand lamellæ of the second segment overlapping that of the left; in the two succeeding segments the left hand lamellæ overlaps the right, and finally the disposition of the lamellæ in the fourth segment is like that in the second. These cases appear, however, to be irregular, and not to be characteristic of different species. When these brood lamellæ are fully developed the sterna

[1] *Archiv f. Naturgesch.*, 1879, *loc. cit.* [2] *Loc. cit.*, p. 20.

of the thoracic segments undergo a retrograde development and almost disappear, and the animal does not appear to take any nourishment; in all the mature females that I have examined the young appear to be actually contained within the body of the mother, the alimentary canal is pressed up against the dorsal surface of the body, and its cavity is reduced to a minimum; a delicate chitinous membrane is all that remains of the thoracic sterna.

Secondary Sexual Characters.—The males of *Serolis* also differ from the females in a number of secondary sexual characters, which may be divided into two groups—(1) those which are common to all the species of the genus, (2) certain other characters which are confined to one or more species.

1. As a general rule the males of *Serolis* are somewhat larger than the females; this is certainly the case with *Serolis bromleyana* and *Serolis neœra*, in which species the males are not only longer but also broader, owing chiefly to the greater development of the spine-like epimera so characteristic of these two species. In *Serolis cornuta*, *Serolis schythei*, and *Serolis latifrons* the difference in length between the two sexes does not appear to be great, but the males are considerably broader than the females; especially is this so in *Serolis schythei*, where the proportion between length and breadth is almost reversed in the two sexes; in the male the breadth is greater than the length, in the female, on the contrary, the length is greater than the breadth, and the difference between these two dimensions is very near to being the same in both sexes. In *Serolis antarctica* and *Serolis gracilis* the males have a greater antero-posterior as well as transverse diameter than the females.

Among the Australian species, on the contrary, the females appear to be larger than the males, but since the number of specimens in each case was extremely small, it is impossible to speak with certainty. Of *Serolis australiensis* two out of the three specimens are males and smaller than the single female specimen; of *Serolis tubercutata* the Challenger obtained two specimens, one of each sex, and here again the male is the smaller; the male specimen also which has been described by Grube[1] is of about the same size as the male which I have examined; finally, in the only other Australian species, *Serolis pallida*, of which more than a single example was obtained by the Challenger, the female is larger than the male.

In the majority of species of *Serolis* there is a difference in the length of the epimera in the two sexes, and this difference is most strikingly shown in *Serolis gracilis;* in the males of this species the epimera gradually increase up to the sixth, the last thoracic epimera, which are enormously elongated and extend beyond the termination of the caudal shield for a considerable distance.

In the female the epimera are very much reduced in size; the sixth pair, instead of being prolonged beyond the caudal shield, do not reach as far as its extremity.

[1] *Loc. cit.*, p. 227.

In most other species the same conditions occur, and a comparison in detail of the posterior epimera, which differ more in length in the two sexes than the epimera of the anterior segments, will be found under the description of species.

Some few species do not show these differences; in *Serolis paradoxa*, for example, the males, on a superficial view, are indistinguishable from the females, and the difference in size between the two sexes is hardly if at all marked.

As a general rule the sterna of the three anterior abdominal segments serve to distinguish the sex of the individual; in the females the middle portion is commonly prolonged into a stout spine, while in the males this structure is not present, and the posterior margin of the segments is straight or slightly concave. In a great number of species, however, the two sexes do not differ at all in this way.

Another marked secondary sexual character, which is quite universal in the form of the third thoracic appendages; in the females this pair of appendages is entirely similar to the succeeding ambulatory limbs; in the males, on the contrary, the penultimate joint is swollen and furnished on the inner side with a number of peculiar modified spines, the terminal joint is recurved, and the appendage thus forms a prehensile organ very like the second thoracic appendage. Of *Serolis tuberculata* Grube states (*loc. cit.*, p. 230)—"Die Füsse des 2ten Fusspaares sind weniger ausgeprägte Greiffüsse als bei andern Arten; zwar zeichnet sich das 3te und 4te Glied durch seine Kürze vor den entsprechenden der folgenden Beine aus, allein das Handglied ist weniger breit als sonst, sein Innenrand nicht längs der ganzen Schneide mit Zähnen besetzt, und die Klaue scheint nicht so zum einschlagen geeignet zu sein. Die Zähne sind ziemlich lang und stachelförmig mit einer Andeutung von Nebenzacken." The male specimen of this species which I have examined myself does indeed display such differences from the ordinary structure of these appendages in all other *Serolis* as Grube describes; both specimens are, however, evidently immature; the characters that he mentions exactly correspond to the appendages of immature males (see *infra*, p. 27).

These appendages are used by the male during copulation; the claw is firmly imbedded in the epimera of the female, so firmly that the individuals can hardly be separated without injury.[1]

In all species of *Serolis*, as in many other Isopoda, the second pair of abdominal appendages bear a long penial filament; these are a continuation of the lower margin of the endopodite of the limb, and reach in some cases as far back as the end of the caudal shield; in other species they are not quite so long. The end of these filaments is blunt and rounded, and not furnished with any aperture; it seems possible for this reason that the two are approximated during copulation, and form a groove down which the spermatophores pass; the fact of the male generative apertures being placed so closely together seems to favour this supposition.

[1] Studer, Isopoden gesammelt während der Reise, &c., *loc. cit.*

In the females there is no trace whatever of these penial filaments.

2. Under this head I may briefly review certain outward differences in male and female individuals which are peculiar to one or more species, and of which a fuller description is given below.

In *Serolis convexa* (Pl. VI. fig. 10) and *Serolis gaudichaudii* the second pair of thoracic appendages in the male are furnished with a tuft of pinnate hairs upon the inner side of the antepenultimate joint, and in the male of the former species, at any rate, the sterna of certain of the thoracic segments are provided with patches of similar hairs.

In *Serolis septemcarinata* the epimera of the males bear a row of five or six elongated ridge-like tentacles on the under surface which are entirely wanting in the female.

The females of *Serolis neœra* are distinguished from the males by the far greater development of the frontal "sense organ"[1] (*cf.* Pl. V. figs. 1, 3), and the epimera themselves show certain differences in the two sexes, being considerably wider in the male, where the anterior margin from the point of junction with the lateral angle of the cephalic shield slopes gradually backwards and outwards to the termination of the epimeron; in the females the anterior margin passes at first directly backwards almost parallel to the longitudinal axis of the body, and then slopes outwards so that in this sex the anterior epimera look as if a piece had been cut out.

Another sexual difference is found in *Serolis gracilis* and *Serolis convexa*, and is mentioned by Audouin and Milne-Edwards as occurring in *Serolis gaudichaudii*.[2] In these species the terminal thoracic appendages of the males are beset with fine hairs, which are similar in shape to the hairs upon the second thoracic appendages of the males of *Serolis convexa* and *Serolis gaudichaudii;* these same appendages in the females do not differ in any way from the preceding thoracic appendages.

On Pl. II. fig. 6 is figured a single joint from the filament of the second antenna of a male *Serolis schythei;* along the inner margin of the joint are a series of delicate fan-shaped lamellæ which I did not succeed in finding in any female example of this species; it is possible, however, that on account of their extreme delicacy they may have been overlooked.

Alimentary Canal.—The alimentary canal of *Serolis* agrees closely with that of other Isopoda; the point to which I may call special attention is the presence of salivary glands, which I have noticed in *Serolis paradoxa* and *Serolis septemcarinata*. On account of

[1] Grube was the first to point out the presence of a transparent oval area on the first epimera which he imagined might cover some sense organ; Dr. Woodward (*Geol. Mag.*, 1883, p. 21) has compared this structure to certain pores which are to be found in many Trilobites occupying an identical position. I have found that this structure exists in nearly all the species of *Serolis*, generally having the form of a deep and narrow groove surrounded by a specially thickened rim; in *Serolis schythei* and *Serolis cornuta* the structure is precisely as described by Grube in *Serolis paradoxa*, and as in that species there is a pore on the under surface of the epimeron exactly beneath it. In *Serolis antarctica* and others I could discover no trace of it. Concerning the minute anatomy of this "sense organ," I am unfortunately able to say nothing.

[2] *Loc. cit.*, p. 19.

its conveniently small size I selected the latter species for anatomical study by means of transverse sections, which I found much better than dissection owing to the state of preservation of the specimens.

On Pl. X. fig. 6 is figured a transverse section through the head of *Serolis septemcarinata* showing the salivary glands *in situ; a* is the aperture of the mouth, *b* the buccal cavity, and *c* points to the ventral wall of the body bounding the mouth; the salivary glands (*d*) are arranged in rosette-shaped aggregations of cells surrounding a central cavity; these cells are highly granular, and stain deeply with carmine; each is provided with a large nucleus which stains rather more deeply than the surrounding protoplasm; the glands are imbedded in the cellular connective tissue of the body, some of the cells of which are shown in the figure (*e*). Similar structures have been observed by Dohrn[1] in *Anceus* and *Paranthura*, and are figured and described by him in his account of the anatomy of these two genera.

The œsophagus, as in other Crustacea, passes upwards into the masticatory stomach, which is furnished with a complicated series of chitinous plates.

On Pl. X. fig. 9 is figured the masticatory stomach of *Serolis bromleyana* viewed from beneath; the "pyloric" end is directed towards the upper margin of the plate.

There is an upper median azygos cardiac plate (*m*); in front of this and below is a cylindrical plate (*LR, RP*) on either side ("Reibe-platte"), the lower surface of which is traversed by a row of rib-like thickenings. On either side of the median plate are three lateral plates (*l, la, lp*), one median, one anterior, and one posterior; the median lateral plate (*l*) is furnished with numerous fine hair-like processes on the under surface. On the ventral surface of the stomach is a large ossicle (*V*) which reaches beyond the commencement of the dorsal azygos piece (*m*), and terminates in a bifurcate extremity; behind this comes the pyloric portion of the stomach, which has four ossicles on either side; two small triangular ossicles (*t*), situated just above the median piece (*V*), and behind three pairs of elongated ossicles which are furnished with delicate hairs directed inwards and form a sieve-like structure; the outermost ossicle (2) is connected both with the median ventral ossicle (*V*) and the lateral plate (*R.P.*) of its own side; *s* points to the pyloric aperture.

In *Serolis antarctica* the masticatory stomach is entirely similar.

In *Serolis paradoxa* the masticatory stomach apparently differs from that which has just been described by the very incomplete calcification of the cardiac ossicle, which is indeed hardly to be recognised as a distinct ossicle; the ventral median ossicle does not extend so far backwards as in *Serolis bromleyana*, and is less markedly emarginate at its apex.

The masticatory stomach in the two other species in which I have studied it, viz.,

[1] Entwickelung und Organisation von Praniza (Anceus) maxillaris, *Zeitschr. f. wiss. Zool.*, Bd. xx. p. 55, 1870; and also Zur Kenntniss des Baues von Paranthura costana, *Ibid.*, p. 81.

Serolis schythei and *Serolis latifrons*, presents some differences. Fig. 4 is a drawing of the masticatory stomach of *Serolis schythei*, which is entirely similar to that of *Serolis latifrons;* the chief difference from *Serolis bromleyana* is that the lateral ossicle (fig. 4, *l*) is furnished upon the upper surface with short spines in addition to the delicate hairs which clothe its lower surface. The outermost of the three pairs of ossicles which form the pyloric half of the stomach is also more extensive, and bears the ribbed lateral plates (*RP, LP*) upon the anterior edge.

At the junction of the masticatory stomach with the intestine are four cæca which are long and coiled in *Serolis cornuta* (Pl. X. fig. 2); in a specimen of *Serolis neœra* that I dissected there were also four cæca, two situated beneath the gut, and considerably shorter than the other two which lay along the outer margin.

From the masticatory stomach arises the intestine, which is at first wide but gradually narrows towards the rectum; the latter commences at about the level of the fifth thoracic segment, and is separated off from the intestine by an incomplete circular valve; the anus is an oval aperture on the ventral surface of the body between the attachments of the gill plates. The intestine as well as the rectum is provided internally with a series of longitudinal glandular folds.

In a number of small specimens of *Serolis latifrons* mounted on slides in Canada balsam the alimentary canal was distinctly visible; between the wide anterior portion of the intestine and the rectum, which is half its diameter, is a narrow portion of the gut, measuring at its commencement rather less than one half of the diameter of the rectum, and then becoming slightly wider as it approaches the latter.

Nervous System.—The nervous system of *Serolis paradoxa* is figured in Packard's Zoology;[1] Studer has also given a figure and description of the nervous system of *Serolis latifrons;* the former of these two figures appears to represent more strikingly the concentration of the posterior ganglia into a nervous mass where the commissures and connectives between the several ganglia are lost.

I have studied the nervous system of the genus in two species—in young examples of *Serolis carinata* by means of sections and by simple inspection of the entire animal mounted in glycerin; in *Serolis neœra* by dissection.

The nervous system of both these species, as in other Crustacea, shows a relation to the segmentation of the body; the fusion of the anterior segments is accompanied by a fusion of their ganglia, and the same thing has taken place in the posterior region of the body. On Pl. II. fig. 14 is represented the nervous system of *Serolis septemcarinata;* the drawing has been made from a specimen mounted on a slide, but the number of the ganglia has been checked by comparison with a complete series of longitudinal sections through an animal of the same size.

The cerebral ganglia are very large, and present the appearance of being composed

[1] Zoology, Packard, 2nd ed., New York, 1880, p. 397.

of a number of separate lobes; a pair of connectives unite the cerebral ganglia with the ventral chain; the latter is composed of thirteen distinct pairs of ganglia, some of which bear unmistakable evidence of being the result of a fusion between several pairs of primitively distinct ganglia; this is particularly the case with the anterior of the ganglia, which are seen in longitudinal section to be composed of two fused ganglia. The eight following ganglia belong apparently to the thorax. Of these the three anterior[1] are separated from each other by considerably longer connectives than those which unite the posterior thoracic ganglia; the latter get closer and closer together (in correspondence with the diminished size of the segments to which they belong), and the last pair of thoracic ganglia are hardly separated from the fused ganglionic mass belonging to the abdomen; a careful examination of the latter, especially by the help of longitudinal sections, shows that it is in reality composed of six pairs of distinct ganglia, the last of which is considerably larger than the rest, inasmuch as it has to supply the telson as well as the last abdominal segment. The abdominal ganglia occupy only the first three segments of the abdomen.

In *Serolis neœra* the fusion of the posterior and of the anterior ganglia is even more marked.

In the cephalothorax there are three pairs of ganglia, of which the posterior is much the largest. This is united by a long connective with the next thoracic ganglia, which is situated at the posterior extremity of the second free thoracic segment; it is clear, however, that it belongs to the segment in front, since it was quite easy to trace the nerves passing forwards to this segment. The fourth thoracic ganglion is closely connected with the succeeding thoracic and the abdominal ganglia, the whole forming an elongated oval mass lying in the posterior thoracic and anterior ten abdominal segments; the demarcations between the four anterior pairs of ganglia could be recognised by the stout nerves given off on either side to their respective segments; of the posterior ganglia, however, it was impossible to discover how many there were; a vast number of nerve filaments take their origin on either side, and afford no indication of the number of ganglia, two of these passing in a direction parallel to the longitudinal axis of the body from the hinder end of the ventral chain are especially large; they supply the telson.

Eye.—With one exception—*Serolis antarctica*, which is perfectly blind—all the known species of *Serolis* are provided with a pair of eyes situated upon each side of the cephalic shield at about the middle of its antero-posterior diameter; the eye has usually a reniform outline, and in general aspect recalls that of the Trilobite, with which it has been compared; more rarely it is oval (*Serolis bromleyana*), and in *Serolis minuta* it is almost circular.

In all the shallow-water species the eye is relatively small, but very conspicuous from the abundant deposition of pigment; in all the deep-sea forms, with the exception of

[1] This is not clearly shown in the figure owing to an oversight.

Serolis gracilis, in which species the eye seems to be disappearing (see p. 24), it is relatively larger but not so conspicuous, owing to the fact that little or no pigment is present; these external points of difference between the eyes of the deep-sea and shallow-water species are accompanied by very striking differences in their minute structure. Since, however, the shallow-water species agree more closely with other Arthropoda in the structure of the eye, it will be more convenient to commence with them before describing in greater detail the deep-sea species.

Among the shallow-water species I have investigated the minute structure of the eye in the following:—*Serolis schythei*, *Serolis paradoxa*, *Serolis latifrons*, and *Serolis cornuta*. In all there is a fundamental similarity, but there are certain differences in detail.

In *Serolis schythei* the eye (Pl. IX. fig. 2) is facetted externally, and a transverse section shows that each facet forms a doubly convex lens, the posterior convexity being more marked than the anterior. Corresponding to each lens is a vitreous body (*v*) of an oval conical form, and composed, as in other Isopods, of two halves joined in the middle line; as a general rule the vitreous bodies have the even regular form displayed in the figure, but some are uneven, one half being larger than the other; surrounding the vitreous body are the remains of the two cells which gave rise to them, and above, between the vitreous body and the cornea, are two nuclei ("nuclei of Semper") which belong to these cells. The whole "vitrella"[1] is enclosed in a sheath of deep black pigment cells.

Below the vitrella is the retinula, which consists of only four cells; this is an unusually small number; from Grenacher's work upon the Arthropod eye already quoted, it appears that five or seven cells is the usual number, and in some cases the retinula contains a greater number of cells; *Gammarus locusta* would seem to be the only known Crustacean besides *Serolis* in which the retinula is composed of so few as four elements. Each of the retinula cells is club-shaped when viewed in front (fig. 2); seen laterally they are hatchet-shaped (figs. 18, 19); at about the middle of the cell is an oval swelling where the nucleus is situated; the nucleus is oval in form, the long axis corresponding to the long axis of the cell, and is contained in a cavity; in the interior of each nucleus is a small highly refracting nucleolus. The retinula cells are clothed externally with a coating of pigment, which is more especially developed at the upper swollen extremity and gradually decreases in amount towards the lower end; this pigment appears to be contained in long branched connective tissue cells. The retinal cells themselves, however, do contain intrinsic pigment in addition to this adventitious sheath, as is shown by transverse sections. Fig. 20 represents a series of sections through a single retinula at various points which are indicated in the description of plates; from these sections it may be seen that the retinal cells contain abundant pigment granules within their own

[1] The nomenclature used in this description is taken from Grenacher's Untersuchungen über das Sehorgan der Arthropoden, Göttingen, 1879; and from a Memoir on the Eyes of *Limulus* and *Scorpio* by Prof. Lankester and Mr. A. G. Bourne (*Quart. Journ. Micr. Sci.*, N. S., vol. xxiii. p. 177, 1883).

substance, especially towards the circumference. The nuclei of the pigment cells become conspicuous in teased preparations of the eye depigmented by means of nitric acid.

At the upper extremity of each retinula cell, and lying upon the inner margin, is a clear chitinous rod, the "rhabdomere" (fig. 18, *r*); the four rhabdomeres are more or less closely united to form the rhabdom, which is shown in figs. 2, 5, *r*; the lower extremity of the rhabdom is produced into a fine thread, reaching nearly as far as the pigmented membrane which bounds the inner surface of the eye. Below this membrane, which is of some thickness and pigmented only upon its upper surface, the retinal cells are continued into stout nervous rods which are slightly swollen at the upper end, where they come into contact with the retinal cells.

The pigment sheath of the retinal cells is continued for a short distance along the nerve rods; the latter exhibit transverse markings, and are a little like striated muscular fibres; it is very likely that these structures in other Crustacea have contributed to the erroneous idea that the Arthropod eye possesses intrinsic muscular fibres serving as a focusing apparatus. It has, however, been clearly shown by several investigators that there are no such muscular fibres present.

So far the eye of *Serolis schythei* only differs from that of other Isopoda in unimportant details. I now proceed to describe another structure which enters into the composition of the eye in all the species of *Serolis* that I have examined, but which has not to my knowledge been figured or described as occurring in the eye of any other Arthropod; this structure consists of two large hyaline bodies situated below the rhabdom, and enclosed by the upper extremities of the four retinal cells (fig. 2, *h*). Occasionally only one seems to be present in a single retinula, and very often the size of the two is unequal, one being considerably larger than the other (fig. 10). Each of these bodies is clear and transparent, the substance of which it is composed having very much the appearance of chitin, and I was at first inclined to think that the whole structure in all probability represented the rhabdom of other Arthropod eyes. Seeing, however, that a rhabdom is present—though rather small and inconspicuous—this comparison cannot hold good, and moreover each of these hyaline bodies shows an irregularly shaped granular mass, deeply stained by carmine and other reagents, which would seem to be a nucleus; it is evidently therefore an independent structure and not a product of the retinal cells; the lower end of the rhabdom is imbedded in these two cells, and the filiform prolongation of the same appears to pass through their substance. The large size and transparency of these hyaline cells seems to indicate that they serve as a dioptric medium. I am not able to say whether these structures represent highly modified retinula cells or intrusive connective tissue cells, inasmuch as I have found them already well-developed in the youngest specimens that I have examined.

In *Serolis paradoxa* the structure of the eye is in most respects similar, but each of the cells which compose the retinula secretes in addition to the rhabdomere a small highly

refractive lens-like body or "phaosphere." The shape of these bodies as well as their position varies considerably; sometimes they are quite spherical, occasionally they are oval, and more rarely bean-shaped; they are more usually found in front of the nucleus of the retinula cell, sometimes within its swollen anterior extremity; often they lie behind the nucleus, and in a few cases they were observed in close contact to the nucleus and slightly to one side. The phaospheres of all the four cells of a single retinula in some instances occupied an approximately similar position, though more generally this was not so.

I only succeeded in making out these structures in *Serolis paradoxa;* in *Serolis schythei* and *Serolis cornuta* they appear to be absent.

Serolis cornuta.—In this species the cells composing the retinula are longer and more slender than in *Serolis schythei* or *Serolis paradoxa,* and the pigment upon their outer surface is comparatively feebly developed, being chiefly massed round the rhabdom; in other respects their structure is similar, and very thin longitudinal sections show that intrinsic pigment is present within the cells themselves in addition to the intrusive pigmentiferous connective tissue corpuscles which clothe them externally. The rhabdom is a remarkably complicated structure, and differs greatly from the simple rhabdom found in the two species just described. It is displayed in figs. 3, 9–15, which have been drawn from preparations teased out in glycerin after having been depigmented by means of nitric acid and in figs. 7, 8, 16, 17, which represent longitudinal sections of this portion of the eye undepigmented. In the latter the rhabdom is seen to consist of a number of coiled threads running in various directions and coated externally with a thick layer of black pigment. The lower extremity of the rhabdom projects into the "hyaline cells" and is surrounded by their substance. In fig. 4 is displayed a teased preparation of the eye of *Serolis cornuta* undepigmented, and it may be seen that the rhabdom ends below in blunt rounded prolongations which project into the "hyaline cells"; the lower extremity of each of these prolongations—which indicate the composition of the rhabdom out of four rhabdomeres—is devoid of pigment, so that the rays of light can pass through. In longitudinal sections of course only one or two of these can be seen, though there are in reality four.

The shape of the rhabdom can best be made out by teased depigmented preparations; fig. 3 represents a single retinula prepared in this way; the rhabdom is here seen in profile and resembles an irregular coil of rope projecting below into the hyaline cells (*h*) and continued into a thin filamentous prolongation which appears to pass through the substance of these cells or between them, and extends nearly as far as the lower end of the retinula cells. Figs. 9–15 represent the rhabdom and the two hyaline cells viewed in such a position as to bring out the symmetrical character of the former. The form of the rhabdom, however, differs widely in detail; some of the varieties are displayed in these figures; in all it appears to consist of a median unpaired portion which is continuous below with four symmetrically arranged portions which project into the substance

of the two hyaline cells; the median portion is usually formed by a sinuous rod of varying length, which ramifies at its lower extremity into four coils; the whole structure reminds one very forcibly of the Malpighian bodies of the kidney; in some cases the median rod is double, and more rarely (fig. 13) it is represented by four or five pieces; it is possible that these varieties correspond to stages in growth, the more complicated (*e.g.*, figs. 11–13) being the older.

The "hyaline cells," as already mentioned, are two in number in each retinula; the nucleus is situated close to the lower extremity; in sections which have been slightly depigmented the whole of these hyaline cells becomes tinged of a light mahogany brown, with the exception of the nucleus, which remains unstained, and is therefore exceedingly conspicuous; in, *e.g.*, figs. 16, 17, which are drawn from such sections, it may be seen that these cells enclose almost the whole of the rhabdom, and this would seem to suggest that they are concerned in its production and may therefore perhaps be modified retinula cells; the cells themselves are quite homogeneous and transparent—apart, of course, from the nucleus—and in section appear exactly similar to the vitreous body; they are, however, more transparent and quite colourless, whereas the vitreous body is always of a chitin-yellow colour. In a teased preparation of the eye of *Serolis cornuta* the addition of strong nitric acid dissolves out the pigment, which is at first absorbed by the hyaline cells, causing them to assume a very remarkable appearance, represented in Pl. X. fig. 1; these cells become quite granular with a crenated outer margin and of a dark greyish-black colour; when the process of depigmentation has gone on a little further the pigment is dissolved out of the hyaline cells, leaving them perfectly transparent and smooth, or at most with a slight mahogany brown tinge.

Among the deep-sea species of *Serolis* the eye is entirely absent in *Serolis antarctica;* its place, however, is occupied by a small tubercle not more than 1 mm. in extent, on either side of the cephalic shield; the posterior border of the latter in consequence is more regular, and the postero-lateral projections which correspond to the eyes are but slightly marked; the two tubercles have the same microscopic structure as the rest of the chitinous integument, and show no traces of facets; their interior is filled with a plug of connective tissue, in which no vitreous bodies or retinal elements could be detected. In *Serolis gracilis*, another deep-sea form, the eyes present some curious peculiarities. In two specimens the eyes are well developed, though small, and resemble entirely the eyes of *Serolis bromleyana;* they are conspicuous from their whitish colour, which contrasts with the surrounding integument; in one specimen the ocular protuberance is only partly occupied by the optic tissues, the rest being exactly similar in colour to the general integument of the body; in another specimen there is no trace whatever of any optic structures, though the oval-shaped elevations of the eye are present but dark bluish in colour like the rest of the integument. In this species, therefore, the eye seems to be just on the verge of disappearance.

Serolis bromleyana.—That portion of the chitinous integument that covers the eye is modified and differs from the rest by its comparative thinness, and by the absence of the characteristic scale-like sculpturing; corresponding to each element of the eye is a thickening of the cornea, which is, however, very slightly developed in comparison with other species, and indeed the two surfaces of the cornea appear in transverse section to form two nearly straight parallel lines, the lower surface alone showing a series of undulations of unequal extent. Pl. X. fig. 5, and Pl. IX. fig. 2, represent transverse sections through the cornea of *Serolis bromleyana* and *Serolis schythei* respectively; the conspicuous corneal lenses of the latter type are in very marked contrast to the feeble indications of these structures in *Serolis bromleyana.*

The tissues of the eye itself have evidently undergone considerable degeneration, and this, coupled with the fact that the specimens were by no means well preserved, renders any satisfactory comparison of their structure with that of the shallow-water species of *Serolis* and the Arthropoda generally extremely difficult. I describe the facts as they appear to me.

Pl. X. fig. 5 is a diagrammatic representation of a transverse section through the eye; beneath the cornea are a series of more or less cup-shaped masses of unequal size and of a granular appearance; occasionally several of these bodies appeared to have become fused together at their upper extremity, and in a few instances a short upward prolongation of the subjacent tissue into the substance of the body gave it the appearance of being originally formed out of two separate halves; the granular yellowish coloured matter of which these structures consist is almost entirely unaffected by carmine, which stains deeply the surrounding tissues, and is only slightly stained by hæmatoxylin. In teased preparations of the eye these structures are easily separated, and are seen to have an oval contour; from their position they would appear to correspond to the vitreous body, and in their general characters recall the vitreous bodies of the type of eye termed by Grenacher "pseudoconous." The compound eyes of the Arthropoda have been arranged by Grenacher[1] into three groups—(1) euconous eyes, (2) aconous eyes, and (3) pseudoconous eyes. In the first group the cells lying behind the facets secrete in addition to it a highly refractive vitreous body or "Kristallkegel," which is composed of as many segments as there are cells; in the second group the cells remain unaltered and secrete no vitreous body; in the third group these cells secrete "a soft fluid or semifluid substance" which represents functionally the vitreous body of euconous eyes. It seems to me very possible that the granular appearance of the vitreous body in the deep-sea *Serolis* has been caused by the coagulation (by alcohol) of a semifluid substance. Pseudoconous eyes, which according to Grenacher are only to be found in the order Diptera, are further distinguished from euconous eyes by the fact that the nuclei of the cells of the vitreous body (the so-called "nuclei of Semper") remain *below* the

[1] Sehorgan der Arthropoden, Göttingen, 1879.

vitreous body itself, instead of being placed *above* it and in close proximity to the cornea.

I was unable to detect with certainty these nuclei of Semper in the eye of *Serolis bromleyana*, but in another deep-sea form, *Serolis neæra*, having an eye of similar structure they were very conspicuous, and situated above the "vitreous body" between it and the cornea. Each of the vitreous bodies of *Serolis bromleyana* is enclosed in a cup-shaped sheath of tissue (Pl. X. fig. 5) in which no trace whatever of any structure could be made out. This sheath possibly corresponds to the pigment sheath which encloses the vitreous body in other Arthropoda, but in *Serolis bromleyana* it is entirely free from pigment. Below this portion of the eye, and corresponding to each of the vitreous lenses, is a roundish mass of cells which are separated into groups by ramifying trabeculæ of pigmented connective tissue; from the posterior end of this mass of cells a delicate bundle of nerve fibres arises which passes back to the ganglion; it is clothed externally by a layer of pigmentiferous ramified cells continuous with those in front.

The eyes of *Serolis neæra* resemble in external characters the eyes in the shallow-water species of *Serolis;* they are distinctly faceted, and a great deal of pigment is present; they are also proportionately larger than in any of the shallow-water species.

The minute structure, however (fig. 3), agrees in the main with that of *Serolis bromleyana*, but is a little less degenerated; the cornea, as already stated, is distinctly faceted; beneath each facet are two large and conspicuous nuclei ("nuclei of Semper"), these are round or oval, sometimes pear-shaped; they are surrounded by a distinct membrane showing a double contour, and contain a highly refractive nucleolus. The vitreous bodies, like those of *Serolis bromleyana*, are of an irregular oval form and granular opaque consistency; the upper half is encircled by a ring of pigment. At the lower end of each is a roundish mass of small nucleated cells (*g*), probably nerve cells, and these are connected posteriorly with a nerve bundle, partly sheathed with pigment cells, which extends into the mass of nerve cells dividing it up into lobules. Fig. 8 is a single element isolated by teasing in glycerin; the vitreous body (*V*) is very distinctly cup-shaped.

The results of my investigations into the minute structure of the eye in *Serolis* may be briefly summed up as follows:—(1) The shallow-water species invariably possess well-developed eyes which are fundamentally similar to those of other Isopoda, but differ in several particulars; the retinulæ are composed of only four cells; the rhabdom is often a highly complicated structure unlike that of other Crustacea. Another element unrepresented (?) in the eyes of other Crustacea is present, consisting of two large hyaline nucleated cells placed below the rhabdom and between the retinal cells. (2) In the deep-sea species the eyes are either altogether absent (*Serolis antarctica*), or, if present, show signs of structural degeneration; no retinula, at least nothing comparable to the retinula in the eyes of the shallow-water species, is present, but the vitreous body is represented. The vitreous bodies may be enclosed in a sheath of

pigment (*Serolis neœra*), or there may be no pigment present (*Serolis gracilis*, *Serolis bromleyana*).

Development.—Several of the species of *Serolis* contained eggs within the brood cavity in various stages of development, and although these embryos were not sufficiently well preserved to admit of any examination by means of sections, I have been able to note down some developmental facts which have an important bearing upon the affinities of the genus. The development history of *Serolis*, so far as I have been able to trace it, is strikingly similar to that of the Cymothoadæ, which has recently been worked out in detail by Mr. J. F. Bullar.[1] The Isopoda generally differ from the Amphipoda in that the embryo has a dorsal flexure in the former group and a ventral flexure in the latter. Thus Fritz Müller (Facts for Darwin, p. 71) says—"The curvature of the embryo upwards instead of downwards was met with by me as well as by Rathke in *Idothea* and likewise in *Cassidina*, *Philoscia*, *Tanais*, and the Bopyridæ; indeed I failed to find it in none of the Isopoda examined by me." And at p. 74—"The Amphipoda are distinguished at an early period in the egg by the different position of the embryo, the hinder extremity of which is bent downwards." In the Cymothoadæ—at least in those species which are treated of by Bullar in the paper from which the above quotation has been made—the embryo is intermediate between the typical Isopoda on the one hand and the Amphipoda on the other; it only occupies the ventral surface of the egg, and does not extend so far towards the dorsal surface as in the Isopoda generally, and the telson is bent downwards as in the Amphipoda. In *Serolis* the embryo is exactly similar, and on Pl. X. fig. 7 I have figured a young embryo of *Serolis antarctica;* if this figure be compared with the figures of *Cymothoa* in Mr. Bullar's paper, the close similarity between the two will be at once apparent.

This fact appears to me to be very strong evidence in favour of Milne-Edwards's view concerning the zoological position of the Serolidæ, which are regarded by him as a division of the Cymothoadæ.[2]

Post-Embryonic Development.—As in many other Isopoda, the males of *Serolis* when first hatched show none of the distinctive secondary sexual characters of males; the time at which they assume these characters differs in different species.

In *Serolis cornuta* the males are at first exactly like the females in general aspect; the body is more oval than in the fully-developed males, being considerably narrower proportionately; the thoracic appendages of the third pair are, as in the females, similar to the succeeding thoracic limbs; the penial filament of the second abdominal appendages is short, and the sterna of the free abdominal segments resemble those of the female in being

[1] *Phil. Trans.*, vol. clxix. p. 505, 1879.
[2] *Hist. Nat. d. Crust.*, 1840, t. iii.

furnished with a median spine. On Pl. I. are figures of a female (fig. 2), a fully developed male (fig. 1), and a young male (fig. 3) of *Serolis cornuta*, which are drawn exactly of the natural size; and judging from the very slight difference in length between the immature and the fully developed male, it would appear that the male does not acquire all its secondary sexual characters until the last moult, though the comparatively greater breadth of the body, which also distinguishes the males of this species from the females, is recognisable somewhat earlier.

The comparatively small number of specimens (seven) of *Serolis neœra* makes it impossible to state with any accuracy the time at which the males assume their proper sexual characters; the facts are as follows—of the four male species two are completely adult, measuring 42 mm. in length, the remaining two are immature, the largest measuring 25 mm. in length; this specimen has the general appearance of a female in its comparatively short epimera, absence of modification in the third thoracic appendage, and in all the other secondary characters by which the males of this species differ from the female, with the exception of the frontal "sense organ," which resembles that found in the adult males, and is not greatly developed as in the females; from this it appears that those secondary sexual characters in which the males of this in common with other species differ from the female appear comparatively late, while the one sexual character peculiar to the species is developed early.

In *Serolis schythei* the males reach maturity much sooner than in *Serolis cornuta;* the largest male specimen in the Challenger collection measures 30 mm. in length by 38 mm. in breadth; the smallest male specimen, with fully developed secondary sexual characters, is 16 mm. long by 19 mm. broad; another male specimen, in which the sex could only be detected by the position of the generative apertures and by the short penial filament, measures 15 mm. in length by 17 mm. in breadth; in this species, therefore, the secondary sexual characters which distinguish the male appear comparatively early, and in immature males, which in other respects are outwardly like the females, the greater proportionate breadth is recognisable; this character is the first to appear, as also apparently in *Serolis cornuta*.

Serolis bromleyana.—In this species the males differ from the females in the third thoracic and second abdominal appendages, and also in the epimera, which are shorter in the female and slope downwards at a less angle with the longitudinal axis of the body. The young males, as in other species, are closely similar to the females, but acquire the secondary sexual characters peculiar to the males at a comparatively early period; the largest male specimen of *Serolis bromleyana* measures 54 mm. in length, the smallest male, which shows all the secondary characters peculiar to its sex, measures 25 mm. in length; the largest male specimen, which has not yet acquired its proper secondary sexual characters, is 21 mm. in length; another specimen 22 mm. in length is nearly adult; the penultimate joint of the third thoracic appendage is swollen

as in the males, but the terminal claw is not yet reflected back. A single male specimen of this species was dredged at Station 164A, which presents some interesting peculiarities in this respect; although only 15·5 mm. in length, it has all the secondary sexual characters of an adult male; the epimera are long and project outwards, the anterior ones nearly at right angles to the longitudinal axis of the body, and the third thoracic appendages are fully developed into prehensile organs; the three middle joints of these appendages, however, are not provided with the soft sensory hairs which I have noticed in nearly all the specimens from Station 168; the large male specimen from Station 156 is also characterised by the same absence of sensory hairs upon this appendage, and it appears to me to be just possible that the males of this species are dimorphic, one set being characterised by the possession of tufts of sensory filaments upon the third thoracic appendages, and the other set differing by the absence of those structures, and also by the fact that the individuals acquire their own proper secondary characters at an earlier date. It is also possible, of course, that this character may be a mere local variation, but in this case its occurrence in individuals from two such widely separated localities as Stations 164A and 156 is not a little remarkable, especially when we consider that the depths which the species inhabit are so different (400 and 1975 fathoms) in these two localities.

The time at which the females of *Serolis* attain to sexual maturity corresponds in every case to that observed in the case of the males.

In *Serolis cornuta* only the largest female examples had the ovigerous lamellæ fully developed, though rudiments of these structures are apparent in many of the smaller individuals.

In *Serolis schythei*, corresponding to the early sexual development of the male, the Challenger collection contains a female specimen only 13 mm. in length, but having the brood lamellæ fully developed and containing eggs.

Of *Serolis bromleyana* there is an adult female dredged at Station 168, only 22 mm. in length; in this species, as already stated, the males acquire their secondary sexual characters at a corresponding age.

DESCRIPTION OF SPECIES.

The following is a complete list of all the species of *Serolis* that are known to me either from the specimens contained in the Challenger Collection or from published descriptions, with the localities and depths at which they occur, and a reference to the first published description; they are arranged in order of discovery.

1. *Serolis paradoxa* (Fabr.) (= *Serolis orbignyi*, M.-E.), Mantissa Insectorum; Patagonia and the Falkland Islands, New Zealand (?), Senegal (?), 5 fathoms.
2. *Serolis trilobitoides* (Eights), Trans. Albany Inst., 1833; South Shetlands, Patagonia, a few fathoms.
3. *Serolis gaudichaudii*, Aud. and M.-E., Arch. d. Mus., 1841; Valparaiso, a few fathoms.
4. *Serolis planus*,[1] Dana, United States Expl. Exp.—Crustacea, part ii. p. 794, 1852; Patagonia, a few fathoms.
5. *Serolis convexa*, Cunningham, Trans. Linn. Soc. Lond., 1871; Patagonia, a few fathoms.
6. *Serolis schythei*, Ltk., Vidensk. Meddel. f. d. nat. Foren. i Kjøbenhavn, 1858; Patagonia, 4–55 fathoms.
7. *Serolis acutangula*, Gr.; Locality ?
8. *Serolis tuberculata*, Gr., Archiv f. Naturgesch., 1875; Bass Strait.
9. *Serolis latifrons* (White), Miers, Ann. and Mag. Nat. Hist., Ser. 4, vol. xvi.; Kerguelen, Crozets, Acukland Islands, 1–210 fathoms.
10. *Serolis septemcarinata* (Miers) (= *Serolis ovalis*, St.), Ann. and Mag. Nat. Hist., Ser. 4, vol. xvi.; Marion Island, Prince Edwards Island, Kerguelen, 1–150 fathoms.
11. *Serolis cornuta*, Studer, Archiv f. Naturgesch., 1879; Crozets, Kerguelen, 1–120 fathoms.
12. *Serolis serrei*, Lucas, Bull. Ent. Franç.; Patagonia, a few fathoms.
13. *Serolis carinata*, Lockington, Proc. Calif. Acad. Nat. Sci.; San Diego, California.
14. *Serolis bromleyana*, Suhm, Proc. Roy. Soc. Lond., vol. xxiv. p. 591; off east coast of New Zealand, between New Zealand and Australia, at lat. 37° 53′ S., long. 163° 18′ E. (near Antarctic Ice-Barrier), 410, 700, 1100, and 1975 fathoms.
15. *Serolis necera*, F. E. B., Proc. Zool. Soc. Lond., 1884, pt. iii. p. 331; off Rio Janeiro, 600 and 2040 fathoms.
16. *Serolis gracilis*, F. E. B., *loc. cit.*; off Pernambuco, 675 fathoms.
17. *Serolis antarctica*, F. E. B., *loc. cit.*; off Pernambuco, 410 fathoms; near Crozets, 1375 and 1600 fathoms.
18. *Serolis australiensis*, F. E. B., *loc. cit.*; Australia, 38 fathoms.
19. *Serolis elongata*, F. E. B., *loc. cit.*; Australia, 30 fathoms.
20. *Serolis pallida*, F. E. B., *loc. cit.*; Australia, 35–40 fathoms.
21. *Serolis longicaudata*, F. E. B., *loc. cit.*; Australia, 38 fathoms.
22. *Serolis minuta*, F. E. B.; Australia, 38 fathoms.

From the above list it will be seen that the new species obtained by the Challenger are nearly as many as those previously known. Besides the nine new species already briefly

[1] It seems to me legitimate to alter the termination "*us*" into "*a*" as done by Grube; I have accordingly followed Grube in the text.

noticed by myself and by Dr. v. Willemoes Suhm, there are in the Challenger collection seven other species which have been more or less fully described by previous writers; these are *Serolis paradoxa*, *Serolis schythei*, *Serolis convexa*, *Serolis tuberculata*, *Serolis latifrons*, and *Serolis septemcarinata*; some notes upon these species will be found below.

Of the remaining six species, *Serolis acutangula* is probably identical with some other form, since Grube, who originally described it in 1871, omits all mention of it in his subsequently published (1875) Monograph of the genus; it is therefore useless to recapitulate or make any comments upon his description here. I have quoted the reference to this description in the list of papers at the beginning of this Report. *Serolis trilobitoides* is closely allied to if not actually identical with Studer's *Serolis cornuta*; the figure of this species which is given by Eights is not very good,[1] and the description, which does not entirely agree with the figure, is not quite complete enough to make it certain whether this is a good species or not.

Serolis plana certainly comes very near to *Serolis convexa*, and under the description of the latter species I have indicated the points of resemblance and difference between the two. *Serolis gaudichaudii* resembles very closely both *Serolis plana* and *Serolis convexa*, but is nevertheless an undoubtedly distinct species; the points in which it differs from the two latter are indicated under the description of *Serolis convexa*. The two remaining species, *Serolis sertei* and *Serolis carinata*, require a fuller description.

The former species is described by Lucas in the following terms:[2]—"Elle est plus large que longue, arrondi, testacée et finement tachée de points bruns. Les six premiers segments thoraciques constituent de très grandes lames pointues falciformes ponctuées, transparentes et non dentelées sur leur bordes comme chez le *Serolis trilobitoides*. Le dernier segment abdominal, tricaréné non dentelé, plus large que long arrondi et légèrement sinueux dans le milieu de son bord postérieur presente une épine assez grande, aiguë, de chaque côté de ses bords latéro-postérieures. La région buccale, les pattes ainsi que tout le dessous du corps sont d'un jaune testacé. Les antennes sont testacées maculées de brun." This species, which attains a length of 27 mm. and a breadth of 36 mm., was obtained by the French vessel "Magicienne" in the Strait of Magellan. Lucas mentions that it is closely allied to *Serolis trilobitoides*, but it seems to me, from the above quoted description, that it is probably more nearly related to *Serolis schythei*.

It is to be hoped that a fuller description of this species as well as of *Serolis carinata* will be published. *Serolis carinata*, which is one of the most interesting species of the

[1] Studer (*Archiv f. Naturgesch., loc. cit.*, p. 21, note) refers to a supposed error on the part of Eights; the anterior antennæ are said to be represented in Eight's figure as if they originated below instead of above the posterior antennæ. This is not, however, the case with Eight's figure, but with Audouin and Milne-Edwards's copy of the figure which is introduced into their Monograph of the genus (*loc. cit.*, pl. ii. fig. 11); the absence of shading here does make it appear as if the anterior antennæ originated below the posterior.

[2] *Bull. Soc. Ent. Franç.*, sér. 5, t. viii. p. cxlv and cxlvi.

genus, on account of its occurrence so far north as California, has been briefly characterised by Lockington[1] as follows:—"Thorax and abdomen conspicuously keeled upon the centre of every segment; the first segment slightly waved on its posterior margin, the curve of the segments increasing rapidly in such a manner that the last entirely encloses the free abdominal segments on their sides. Caudal segment rounded at the extremity, with two marginal teeth on each side at a considerable distance from the extremity, the central carina running the entire length of the segment; last basal joint of inner antennæ longer than the flagellum; flagellum of outer antennæ much shorter than either of the two of the preceding basal joints, and last basal joint about equal in length to the penultimate. Eyes large, reniform, conspicuous. The texture of the upper surface of a dried specimen under a two-thirds power has a somewhat squamate appearance. Colour a greyish-brown, diversified with dots and irregular markings of black; hands long and slender; dactylos equal in length to the manus.

"Length, 0·21 inch; width, 0·16 inch."

Two specimens from San Diego, California.

1. *Serolis paradoxa* (Fabricius) (Pl. V. figs. 12–14).

Oniscus paradoxus, Fabricius, Mantissa Insectorum, Hafniæ, 1787, t. i. p. 240; Systema Entomologiæ, Flensburgi et Lipsiæ, 1775, p. 296.
Cymothoa paradoxa, Fabricius, Entomologia Systematica, Hafniæ, 1792–98, Suppl., p. 304, and t. ii. p. 503.
Serolis fabricii, Leach, Dict. d. Sci. Nat., 1818, t. xii. p. 340.
Serolis orbignyi, Audouin and Milne-Edwards, Arch. d. Mus. d' Hist. Nat., 1841, t. ii. p. 25.
Serolis orbigniana, Milne-Edwards, Hist. Nat. d. Crust., vol. iii. p. 232.
Serolis paradoxa, Miers, Crustacea collected during Survey of H.M.S. "Alert," Proc. Zool. Soc. Lond., 1881, p. 61.

Serolis paradoxa is the type species upon which the genus *Serolis* was founded by Leach. The animal was first obtained on the shores of Patagonia by Sir Joseph Banks at the close of the last century, and these specimens were described by Fabricius as *Oniscus paradoxus*; in a subsequent work Fabricius altered the name to *Cymothoa paradoxa*. In the twelfth volume of the Dictionnaire des Sciences Naturelles, Leach gave some account of this species which he termed "*Serolis fabricii*." The first full description of the species is contained in the memoir of Audouin and Milne-Edwards,[2] and subsequently Grube[3] in his important Monograph gave a fuller account of this same species, but under the name of *Serolis orbigniana*. In a short note published in the Journal of the Godeffroy Museum,[4] Schmeltz called attention to the identity of *Serolis fabricii* with another species described by Audouin and Milne-Edwards under the name of *Serolis orbignyi*. More recently Miers, in his account of the Crustacea collected during the voyage of the "Alert," has also pointed out the identity of these two species.

[1] *Proc. Calif. Acad. Nat. Sci.*, vol. vii. p. 36.
[2] *Loc. cit.*, p. 25.
[3] *Loc. cit.*, p. 225.
[4] Part xii. p. 161.

I have little doubt that both Schmeltz and Miers are quite right in regarding these two species as identical; it is impossible, either from the description or the figures contained in the memoir of Audouin and Milne-Edwards, to select any characters by which the two species *Serolis fabricii* and *Serolis orbigniana* can be definitely distinguished; such differences as there are appear to me to arise from the fact that the two "species" are in reality merely the males and females of the same species, *Serolis fabricii*.

With regard to the name I have followed Miers and written *Serolis paradoxa*; this name evidently has the priority.

A number of specimens of *Serolis paradoxa* were dredged by the Challenger at the Falkland Islands, and this, together with the adjacent shores of Patagonia, is the only locality which the species is known with certainty to inhabit. According to Leach, *Serolis paradoxa* extends to the west coast of Africa; he makes the following remarks about its distribution (*loc. cit.*, p. 340)—"I have only seen two specimens; one is in the collection of Banks and comes from Tierra del Fuego; the other is in my possession and was given me by Duftesne, who tells me that he received it from Senegal." The specimen from Senegal is now in the British Museum, and is labelled in the handwriting of Leach. The British Museum contains another specimen of *Serolis paradoxa* which is labelled "New Zealand," but I believe that in this case, as in that of *Serolis schythei* to be mentioned later, the locality is not thoroughly authenticated. Miers includes *Serolis paradoxa* in his list of New Zealand Crustacea apparently on the authority of this same specimen.

The males and females of this species are not distinguishable by any well marked difference of size; the males are, however, a little broader proportionately, as is shown by the following measurements taken from two of the largest specimens obtained by the Challenger.

	Length.	Breadth.
Male,	24·5 mm.	25 mm.
Female,	27·5 ,,	26 ,,

The form of the abdominal sterna differs in the two sexes; in the male the outline is somewhat crescentic, the posterior margin being curved and the anterior margin almost straight; in the female each of these segments bears a median spine upon the posterior margin directed backwards and closely overlapping the succeeding segment. In this character *Serolis paradoxa* agrees with *Serolis schythei*, but the spines in the females are longer than in that species. The above measurements do not express the greatest size to which this species attains; there are several specimens in the British Museum somewhat larger, and White states[1] that individuals have been known to reach the great length of 6 inches! This last statement, however, requires confirmation.

Serolis paradoxa is, as Grube remarks,[2] more nearly allied to *Serolis schythei* than to

[1] White, Description of New Species of Insects and other Annulosa, *Ann. and Mag. Nat. Hist.*, 1843, vol. xii. p. 366.
[2] *Loc. cit.*, p. 225.

any other species, but it can easily be distinguished by the smaller epimera and by the shape of the caudal shield, which is more triangular than in that species; as in *Serolis schythei*, the caudal shield is traversed by three longitudinal carinæ, and there is a stout spine close to its anterior border in the middle line; another carina runs parallel to the anterior margin of the caudal shield, of which traces exist in *Serolis schythei*. The transverse ridge of the latter is not found in *Serolis paradoxa*. As in *Serolis schythei*, the first four free thoracic segments have their epimera separated from the terga by a distinct suture.

The antero-lateral areas of the cephalic shield are more extensively developed in *Serolis paradoxa*, so that the breadth of the anterior portion considerably exceeds that of the posterior portion, while in *Serolis schythei* the transverse diameter of the cephalic shield is greatest at about the level of the eyes.

Antennæ.—The filament of the second pair of antennæ in both the male and female is furnished with a series of short recurved hooks; these hooks are not found upon all the joints of the filament, they commence to be visible (in one specimen) on the seventh, and extend as far as the sixteenth; in the last nine or ten of these joints there is a continuous row on the upper surface not far from the inner margin, commencing close to the posterior articulation and extending in a straight line up to the anterior articulation, the row of hooks then bends inwards and follows closely the anterior edge of the joint, terminating at its outer extremity; in the anterior joints the hooks gradually decrease in number until in the seventh joint there is only a short row on the anterior margin.

Similar structures are found in other species (*e.g.*, *Serolis bromleyana*, *Serolis gracilis*, *Serolis septemcarinata*, *Serolis schythei*), though in no case are the hooks so large and conspicuous as in *Serolis paradoxa*.

The inner lobe of the *first maxillæ* is nearly half the length of the outer lobe; it consists (Pl. V. fig. 14) of a straight and narrow stem and an oval wider distal portion furnished with a single spine near the lower border.

The *second pair of maxillæ* has, as in all other species, two smaller anterior lobes and a larger posterior one; the anterior lobe is a trifle smaller than the second, and bears at its free extremity two long spines; the second lobe has five or six, while the largest posterior lobe has some twenty or thirty.

The *maxillipedes* are characterised by the almost square outline of the stipes, which is quite twice the breadth of the lamina; the latter is clothed on the inner surface with fine hairs; the suture which separates it from the stipes is not complete posteriorly.

The *third pair of thoracic appendages* in the male (fig. 13) are very much like those of *Serolis neœra*; the second, third, and fourth joints are furnished with abundant plumose hairs arranged in two rows, one above the other; the upper row spring from a strong ridge which runs at a short distance from the inner margin of these three

joints, while the second row appears to be attached along the inner margin itself; the penultimate joint is swollen and pear-shaped, broader at the base than above; along the inner margin are some fifteen pairs of long cylindrical spines, which are of a rather unusual form; the distal third bears two rows of short cylindrical branches; the centre of the spine appears to be hollow at the base, and the bounding membrane is continued above into a solid axial rod, which projects for a short way beyond the anterior extremity of the spine. This appendage and the peculiar spines upon the penultimate joint are figured by Grube (*loc. cit.*, pl. v. figs. 3, 3, *a*), Grube also states that the spines upon this pair of appendages are alike in both males and females:—"Der Innenrand des 2ten Paares Greiffüsse trägt lange an der Vorderseite gesägte Stacheln, sowohl beim Männchen als beim Weibchen." They are in reality quite different in the female; the fourth joint bears a row of spines arranged in pairs; on the distal half of the joint these spines are strong and serrated along both margins, resembling entirely the serrated spines found upon the other thoracic limbs; posteriorly the serrations become less marked, and the proximal end of the joint has only smooth sword-like spines, the third and fourth joints have none of the soft plumose hairs that are found in the males; their place is occupied by tufts of strong spines, some of which are serrated. In this as in all other species in which the males have the peculiarity here described, the females are invariably different, the third pair of thoracic appendages being in this respect closely similar to the succeeding appendages.

The remaining thoracic appendages are not in any way remarkable. The second joint, which is rather smaller than the first joint, is furnished with a tuft of long hairs upon the inner surface at the distal extremity, among which are a few serrated spines; the succeeding joints, which are approximately of this arm length, the fourth being rather the longest, have a tuft of hairs in the same position, among which are a greater number of serrated spines; in the penultimate joint the long delicate hairs are almost entirely absent, their place being taken by stout spines, many of which are serrated. Along the outer margin of the joints, with the exception of the first, are tufts of short spines, very few of which are serrated.

The three anterior *abdominal appendages*, like those of *Serolis schythei*, have no plumose hairs upon the basal joint.

The suture of the *operculum* is oblique.

The exopodite of the fifth pair of abdominal appendages is bifurcate.

Station 316, February 3, 1876; lat. 51° 32′ S., long. 58° 6′ W.; 4 fathoms; bottom, mud.

2. *Serolis convexa*, Cunningham (Pl. VI. figs. 9–15).

Serolis convexa, Cunningham, Crustacea, &c., of H.M.S. "Nassau," Trans. Linn. Soc. Lond., vol. xxvii. p. 498, 1871.

Serolis convexa, Studer, Isopoden gesammelt, &c., Abhandl. d. k. Akad. d. Wiss. Berlin, 1882, p. 9 (separat Abdrück).

The Challenger obtained only a single specimen of this species, from Port William, Falkland Islands; I have, however, had the opportunity of comparing it with four other specimens in the British Museum which are the types.

Prof. Cunningham's description (*loc. cit.*, p. 498) is as follows:—"Most nearly allied in form to *Serolis planus*, Dana. Body very convex, much more so than in any other species of the genus with which I am acquainted. A prominent carina along the mesial line. Two last segments of pereion distinctly narrower than those which precede them. Last segment of pleon more elongated than in *Serolis planus*, and possessing three well-marked ridges—a median, interrupted in the middle, and two lateral, each terminating in a sharp point. Eyes very prominent, and placed rather near to each other."

Two specimens were obtained by Prof. Cunningham on the north coast of Fuegia.

Prof. Studer has also published some notes upon this species in his account of the Isopoda collected during the voyage of the "Gazelle," and he has pointed out that the chief character by which Grube distinguished *Serolis convexa* from *Serolis gaudichaudii*, viz., a tuft of hairs upon the antepenultimate joint of the second thoracic appendages, is really a secondary sexual character peculiar to the males not only of *Serolis convexa* but also of *Serolis gaudichaudii*; before Prof. Studer's paper came into my hands I had noted the same fact, and alluded to it briefly in my Preliminary Report;[1] the specimen dredged by the Challenger is a male, and it shows another character which I believe to be peculiar to the males; on the sterna of the last three thoracic segments is a small patch about 2 mm. in length by 1 mm. in breadth, distinguishable by its velvety appearance and darker colour from the surrounding integument; this on microscopic examination proved to be covered by a multitude of hairs exactly similar to those found upon the second thoracic appendages, only rather shorter; some of the segments in front also, especially the second, have a small tuft of these hairs.

In other respects the males and females of this species do not differ greatly in appearance; the males are imperceptibly broader in proportion to their length than the females, as shown by the following measurement taken from the male in the Challenger collection and the single female specimen in the British Museum:—

	Length.	Breadth.
Male, ...	25 mm.	20 mm.
Female, ...	25 „	19 „

The sterna of the *abdominal segments* present no differences in the two sexes.

[1] *Proc. Zool. Soc. Lond.*, pt. iii., 1884, p. 330.

The suture dividing the outer lamella of the *opercula* is accurately at right angles to the long axis of the body in the female; it is more oblique, slanting downwards in all the male specimens that I have seen; I am inclined, however, to think that this is rather an individual variation than a mark of sex, inasmuch as nothing of the kind exists in any other species.

Serolis convexa has been figured by Cunningham[1] and by Studer,[2] and as both these figures, especially the latter, show plainly the characters of the species, I hardly think it worth while to introduce another into the present Report.

Serolis convexa can be easily distinguished from *Serolis gaudichaudii* by a number of small characters; the shape of the body is more oval in *Serolis gaudichaudii;* in *Serolis convexa* it is more pear-shaped, owing to the greater length of the caudal shield, which terminates in a more pointed extremity; in both species there is a central and two lateral carinæ; the latter are curved, and follow closely the lateral margin of the caudal shield but at some distance from it; in *Serolis gaudichaudii* these carinæ, especially the two lateral ones, are very faint; in *Serolis convexa* the lateral carinæ are strongly marked, and terminate more or less abruptly in a short spiniform projection at the end of the middle third of the caudal shield; the median carina is only found in the anterior part of the caudal shield, posteriorly it becomes obsolete; another difference between the two species is in the colour, and since this difference is quite constant in all the specimens examined by me (five of *Serolis convexa*, four of *Serolis gaudichaudii*) it is worth noting; *Serolis gaudichaudii* is distinguished by its dark brown colour, darker in the central part of the body, and dotted all over with black spots of various sizes; in *Serolis convexa* the colour is of a uniform pale brown, hardly darker in the middle of the body than upon the epimera. This description of course relates only to specimens preserved in alcohol. Another species closely allied to *Serolis convexa* is Dana's *Serolis plana*, and from a careful comparison of the figures and descriptions given of these two species I find it almost impossible satisfactorily to separate them. The general shape of the body, the form of the epimera, &c., is almost identical in the two. The eyes, however, of *Serolis plana* are stated by Dana to be conical in shape, whereas those of *Serolis convexa*, as in all other species, are distinctly reniform. In *Serolis plana* "the articulation of opercular plates is more nearly transverse than in *Serolis gaudichaudii;*" there is also a lateral tooth on the caudal shield just below termination of carina; the median carina is obsolete posteriorly, and the fourth segment has a low prominence just inside of the epimeral suture. The first character is, as I have already shown, of no use in distinguishing the species; the last character, namely, the presence of a low prominence to the inside of the epimeral suture of the fourth segment, is well marked in the Challenger specimen of *Serolis convexa;* in this specimen all the thoracic segments have a slight prominence, almost indistinguishable in the anterior and posterior ones, but conspicuous in the fourth segment, where it slightly

[1] *Loc. cit.*, pl. lix. fig. 3.

[2] Isopoden gesammelt, &c., *loc. cit.*, Taf. i. figs. 1*a*, 1*b*.

overlaps the succeeding segment and recalls *Serolis minuta*, in which species (see below p. 77) all those prominences are highly developed and project backwards as flat conical processes over the following segments.

The presence of a distinct lateral tooth below the termination of the carinæ does seem to distinguish *Serolis plana* from *Serolis convexa* where there is no such tooth, but it would not be safe, I think, for the present to separate the two until a larger number of specimens of both have been examined.

In all the three species—*Serolis gaudichaudii*, *Serolis convexa*, and *Serolis plana*—the epimera of the second, third, and fourth pairs only are separated from the terga by a distinct suture; in the first two species the anterior epimera are divided by a transverse suture as in so many other species; this suture is, however, not very well marked, and in the specimen of *Serolis convexa* obtained by the Challenger I could not detect any trace of it, though it was distinctly visible in the British Museum specimens.

Appendages.—I give here a somewhat full description of the appendages which have not been described by Cunningham.

Antennæ.—The posterior pair of antennæ are decidedly longer than the anterior pair, reaching as far as the end of the first epimera.

Of the *anterior pair*, the first joint is somewhat broad and quadrangular, the second joint is narrower and a little longer; the anterior and posterior surface of both are covered by a few scattered hairs; the third joint is a cylindrical rod somewhat bow-shaped, and only slightly longer than the preceding joint; the fourth joint is short, about one quarter as long as the third. The filament appear to consist of about twenty-five joints, and each joint has two sensory hairs, one situated near the anterior extremity of the joint, the other near its posterior extremity.

The *posterior pair* of antennæ consist as usual of five joints and a filament.

The first joint is the shortest, the second a little longer and somewhat hour-glass shaped. The third, as usual, inserted in a wedge-like fashion between the second and the fourth; the fourth joint is the longest of the whole appendage, is somewhat bent, and a ridge parallel with the curved lower margin runs along its whole length; the joint narrows towards its extremity, where it articulates with the terminal joint, which is a little shorter and more uniformly cylindrical in shape; the upper margin of the two last joints is furnished with scattered tufts of hairs. The filament has twenty-one joints, which increase in length but diminish in thickness towards its extremity.

The *mandibles* have the cutting edge prolonged posteriorly into two subequal conical teeth; on the upper side are two spines situated one behind the other, the anterior one rather longer and broader.

The *first maxillæ* are in no way remarkable.

The *second maxillæ* (Pl. VI. fig. 14) differ from those of most other species in that the two anterior lobes are not much smaller than the posterior, and are furnished on the outer

edge with eight or nine hairs instead of the usual two. In this respect *Serolis gaudichaudii* seems to resemble *Serolis convexa* (*cf.* Audouin and Milne-Edwards, *loc. cit.*, pl. i. fig. 11).

The *maxillipedes* (fig. 15) are of the usual shape; the lamina is furnished with a number of long hairs upon the lower surface, and the second joint of the palp has a row of similar hairs upon the lower surface, some way from the external margin, which, as usual, has another row of hairs. The third joint of the palp is extremely small, and I was at first inclined to think that this was a mere accident, and that the terminal joint of the palp had been recently broken off, but since Milne-Edwards and Audouin figure[1] the same condition in *Serolis gaudichaudii*, it appears to be characteristic of these two species.

The *second pair of thoracic appendages* are figured on Pl. VI. fig. 10; the tuft of hairs (*a*) have already been noticed as peculiar to the males; several of the spines forming the inner surface of the penultimate joint are more highly magnified in fig. 11; the longer spines, instead of being bifurcate, as is the rule, terminate in a gradually narrowing extremity, the posterior margin of which is beset with a dense row of fine branches.

The *third pair of thoracic appendages* of the male are shown in Pl. VI. fig. 9; the terminal joint is comparatively narrow; from the inner margin arise some eight pairs of conical spines, the axis of which projects beyond the termination as a short filamentous recurved process.

The remaining thoracic appendages were all more or less damaged, with the exception of the sixth, which is figured on Pl. VI. fig. 12; the second, third, fourth, and fifth joints of this appendage are each furnished on the inner side with a tuft of fine pinnate hairs like those on the second pair of appendages in the male; on the distal border of the fourth joint is a row of sharp serrated spines; the terminal claw-like joint of the appendage is sharply bent upon itself at right angles; in *Serolis gracilis* and other species those appendages in the males are similarly modified.

In the *anterior abdominal appendages* the basal joint is triangular in shape, and the projecting (lower) angle is furnished with three plumose hairs in the first of these appendages, and two in the second and third as in many other species.

The *operculo* are traversed by a suture at right angles to the long axis.

Port William. Falkland Islands, 5 to 12 fathoms.

3. *Serolis schythei*, Lütken (Pl. II. figs. 5–13).

Serolis schythei, Lütken, Vidensk. Meddel. f. d. nat. Foren. i Kjøbenhavn, 1858, p. 98, Tab. i. figs. 12, 13.
Serolis schythei, Grube, Archiv f. Naturgesch., 1875, p. 220, pl. v. fig. 1, pl. vi. fig. 1.

This species was originally described from a male specimen by Lütken. Grube in his Monograph of the genus added some details to Lütken's description, and pointed out the differences that exist between the males and the females.

[1] *Tab. cit.*, figs. 12, 13.

The Challenger obtained a great number of specimens of *Serolis schythei*, ranging from the Gulf of Peñas on the north, to the Falkland Islands on the south.

The collection of Crustacea in the British Museum contains one specimen which is labelled "New Zealand," but I believe that it is not quite certain whether this label be correct. With this possible exception, *Serolis schythei* is confined to the shores of Patagonia and the Falkland Islands.

The males of *Serolis schythei* differ from the females by their greater proportional and actual breadth; the largest female specimen in the Challenger collection measures 32 mm. in length by 32 mm. in greatest breadth, the largest male specimen measures 30 mm. in length by 38 mm. in breadth. The greater breadth of the males is owing to the greater length of the epimera. The sixth epimeron in this male specimen measures 17 mm. in length, and extends for the space of about 5 mm. behind the extremity of the caudal shield; in the female these epimera only measure 13 mm., and terminate just beyond the end of the caudal shield. The first abdominal epimera also are longer in the male than in the female; the two sexes also differ, like many other species, in the shape of the abdominal sterna. A third difference is to be found in the antennæ, which are described below.

The colour of *Serolis schythei* (in alcohol) is pale brown, becoming darker in the middle of the body, and diversified with dark brown or black spots, which vary considerably in their number and size in different specimens.

The *cephalic shield* is not unlike that of *Serolis cornuta*, but the prominences and ridges upon its surface are less developed; there is a slight ridge dividing the antero-lateral portions from the rest; to the inside of and behind the eyes are two prominences somewhat triangular in form, which correspond to those in *Serolis cornuta*, but are directed more inwards; between the two is a triangular area which forms the posterior boundary, and owing to the comparatively slight development of the lateral tubercles, lies almost on the same level with them; the disposition of these three prominences is also like what occurs in *Serolis neœra*, which in other respects shows considerable resemblances to this species. The eyes are very large and prominent.

Thorax.—The thoracic epimera are flat and sickle-shaped; as in *Serolis cornuta* the external half of all the epimera projects freely; the articular processes upon the epimera are, however, entirely absent. The first epimera are divided by a transverse ridge. While in the majority of species only the three anterior of the free thoracic segments are divided by a distinct suture into a tergal and an epimeral portion, in *Serolis schythei* there is also a suture separating the terga and epimera of the fourth segment. The posterior margin of the tergum of each segment, with the exception of the first, is curved backwards in the middle line into a short spine; these gradually diminish in size from before backwards; the antero-posterior diameter of the first free thoracic segment is a little less than that of the succeeding segment, which is the largest, and measures 3 mm. in the

female and 2 mm. in the male; the third segment is a little smaller than the second in the female and about the same size in the male; the two last thoracic segments are nearly the same size, the anterior being a trifle the larger, and measuring about one half the diameter of the preceding segment.

On the under surface the sterna of the first two thoracic segments are, as in all other species, divided by sutures into three portions, which resemble in every particular those of *Serolis cornuta;* the posterior thoracic segments are not so fused together as they often are; the sixth is quite distinct from the following ones, and is not divided into a central piece and two wedge-shaped lateral pieces as it is in *Serolis neœra* and other species; a deep groove separates the seventh from the eighth, but it does not extend as far as the suture which marks the boundary between the epimera and sterna.

Abdomen.—The first abdominal epimera are long, and reach beyond the end of the caudal shield in the male, in the female they do not reach quite so far as the end of the caudal shield; the second epimera are short, as in *Serolis neœra,* and only extend for a very short distance down the lateral margin of the caudal shield; they are not distinctly longer in the male than in the female.

The sterna of the abdominal segments differ in the two sexes as already said; in the male the posterior margin is straight, and the two ends project backwards as short spines; the third segment has, in addition, a short median spine; in the female the median portion of all three is produced into a short broad spine.

The *caudal shield* is hexagonal in outline; the posterior end projects as a short spine; there is a distinct median keel and two lateral keels which start from the base of a strong blunt spine situated in the middle line at the anterior end, and terminate in two short spines placed some way in front of the attachment of the uropoda; a transverse ridge, which is prolonged backwards into three short spines, of which the median larger one is upon the longitudinal carina, traverses the caudal shield; viewed in profile, the caudal shield appears to consist of two portions bounded by this transverse ridge; the anterior part, which possibly corresponds to the three fused terminal segments of the body, overlaps the posterior portion or telson; on the other hand it is possible, as suggested by Studer, that the two obliquely running longitudinal keels mark the boundary between the terminal segment of the body and the telson.

The two pairs of *antennæ* are of about the same length. The anterior pair have a short proximal joint with fine hairs upon the upper surface; the two succeeding joints are elongated and somewhat curved; the posterior surface is furnished with fine hairs; the fourth joint is short and oval; the filament is made up of about twenty-three joints, of which the proximal ones are short, but gradually increase in length towards the distal extremity. The second pair of antennæ consist, as usual, of five joints and a terminal filament; the joints increase in length towards the distal end of the antennæ, the last joint being the longest and considerably narrower than the rest, which are about

equal in diameter; the three last joints are beset with hairs arranged in tufts or scattered singly over the surface; the filament is made up of from fifteen to seventeen joints, which, like those of the anterior antennæ, increase in length and diminish in width towards the free extremity; the inner side of each joint, just before the attachment of the joint in front, has a tuft of fine hairs; the anterior margin of the middle joints has a series of short curved spines like those already described in *Serolis paradoxa* (*ante*, p. 35); the antennæ of the males possess a series of delicate lamellar processes (Pl. II. fig. 6) arranged in a single line along the inner side of most of the joints, being absent only from a few of the extreme distal and proximal joints; these structures, which are very probably sensory, take the form of oblong lamellæ with rounded angles, those at the anterior part of the joint are larger and somewhat fan shaped; their surface is marked by a series of grooves radiating outwards from the base of attachment.

The *mandibles* (Pl. II. figs. 12, 13) are markedly asymmetrical, as in other species.

The *maxillæ* present no peculiarities.

In the *maxillipedes* (fig. 10) the stipes and the lamina are not separated by a suture; both are covered with scattered hairs, and a row of finer hairs clothes the inner margin of the latter; at the summit of the terminal joint of the palp is a small protuberance carrying three stoutish hairs similar to those upon this and the preceding joint.

The *first pair of ambulatory appendages* are figured by Grube in his Monograph, but the hairs on the inner side of the penultimate joint are not quite correctly shown; the longer spines (Pl. II. fig. 7) terminate in two flat lateral expansions, and the axis of the spine is continued into the posterior and longer of the two.

The *second pair of ambulatory appendages* of the male (Pl. II. fig. 8) are modified in the usual way (*ante*, p. 13).

In the *remaining thoracic appendages* (fig. 9) the two first joints are subequal in length; the third joint is about half the length of the second, the fourth slightly longer, the fifth shorter than the fourth, and approximately of the same size as the second; the terminal joint is more bent and hook-like in the last pair of appendages than in any of the others. The second joint (in the males only) has a series of about fifteen tubercles close to the inner margin; the third, fourth, and fifth joints are furnished with numerous long and slender hairs as well as stouter sword-like and serrated spines arranged in tufts in the usual way; the last pair of appendages in the male are distinguished from the rest by a greater development of hairs upon the inner surface of the terminal joints; this is an approximation to the marked difference that these appendages show in other species (*e.g.*, *Serolis gracilis*). In *Serolis schythei*, however, these hairs are not, as in the above-mentioned species, in any way different from those upon the rest of the ambulatory limbs.

The *three anterior abdominal appendages* are characterised by the absence of

branched hairs upon the basal joint; in this they agree with *Serolis paradoxa* and the Australian species of the genus.

The *opercula* have the exopodite divided by an oblique suture.

The exopodite of the *gill appendage* is bifurcate.

The *uropoda* are attached close to the termination of the caudal shield, and extend a little way beyond it; they are comparatively large and foliaceous, and furnished with numerous branched hairs.

Station 304, December 31, 1875; lat. 46° 53′ S., long. 75° 12′ W.; 45 fathoms; bottom, green sand.

Station 313, January 20, 1876; lat. 52° 20′ S., long. 67° 39′ W.; 55 fathoms; bottom, sand.

Station 314, January 21, 1876; lat. 51° 35′ S., long. 65° 39′ W.; 70 fathoms; bottom, sand.

Station 315, January 26, 1876; lat. 51° 40′ S., long. 57° 50′ W.; 12 fathoms; bottom, sand, gravel.

Station 316, February 3, 1876; lat. 51° 32′ S., long. 58° 6′ W.; 4 fathoms; bottom, mud.

4. *Serolis latifrons*, White (Pl. II. figs. 1–4).

Serolis latifrons, White, List Crust. Brit. Mus., 1847, p. 106.
Serolis latifrons, Miers, E. J., Ann. and Mag. Nat. Hist., 1875, p. 74.
Serolis latifrons, Miers, E. J., Cat. New Zealand Crust., 1876, p. 117.
Serolis latifrons, Smith, Bull. U. S. Nat. Mus., 1876, vol. iii. p. 63.
Serolis latifrons, Miers, E. J., Phil. Trans., 1879, extra vol., p. 204.
Serolis latifrons, Studer, Th., Archiv f. Naturgesch., 1879, p. 26.

This species was named and described by White from specimens obtained during the voyage of the "Erebus" and "Terror"; one of these specimens is preserved in the British Museum, and was dredged at Rendezvous Cove, Auckland Islands. Miers first described the species from specimens, brought home by the Transit of Venus Expedition from Kerguelen Island, and a more detailed description of the same species is to be found in Studer's Beiträge zur Kenntniss niederer Thiere von Kerguelensland.[1]

A number of specimens were dredged by the Challenger at Christmas Harbour, Kerguelen, 25 fathoms, and two others which present some differences from the typical form were dredged in deeper water (210 fathoms) off Possession Island.

Without entering into any systematic description of this species, which has already been sufficiently done by the above mentioned authors, I may add here a few details.

Studer describes the largest specimens as attaining a length of 40 mm. and a breadth of 30 mm.; these are evidently females, which he says are 1 to 2 mm. less than the

[1] *Archiv f. Naturgesch., loc. cit.*, p. 26.

males. In the Challenger collection the two largest specimens measure 32 mm. in length by 24 mm. in breadth, and are females with developed brood lamellæ. The males are proportionately broader than the females; the length of the largest specimen is 28 mm., its breadth 24 mm.; in one specimen only the breadth was proportionately less than in all the rest, 28 mm. in length by 22 mm. in breadth; the sterna of the free abdominal segments differ but slightly in the two sexes—in the females all have a short, broad, median spine, in the males the two posterior segments are provided with such a spine, which is if anything rather smaller than in the female.

The colour of *Serolis latifrons* (in alcohol) is a dark bluish brown, becoming lighter brown upon the epimera; a very characteristic mark of the species is a white spot upon the anterior part of the cephalic shield, just behind the rostrum; the fifth pair of epimera also are generally lighter in colour than the rest of the body.

The six posterior thoracic epimera are separated from the terga by a distinct suture and the first abdominal segment, which in no other species of *Serolis* known to me has any trace of epimera, has distinct though very minute epimera separated from the tergum by a suture which is continuous with that dividing the epimeron and tergum of the segment in front.

Appendages.—The second pair of antennæ are longer than the first pair; the latter have as usual four joints; the fourth joint is extremely short, its length being only one-third of its breadth; the filament has sixteen joints; in the second pair of antennæ the terminal joint (Pl. II. fig. 4) is prolonged on the ventral side into a process which extends as far as the third joint of the filament; the filament has twelve joints.

The *mandibles* are characterised by the great length of the narrow distal half, which is about half the length of the entire appendage; the masticatory portion of the two mandibles are shown on Pl. II. figs. 2, 3; they present the usual unsymmetrical disposition of the laminæ and spines upon the lower surface.

The *first pair of maxillæ* resemble the same appendages in other species, but the second joint of the palp has seven or eight spines upon its extremity instead of two.

The *second maxillæ* present no differences from other species.

Maxillipedes.—The *lamina* and *stipes* are separated by a complete suture; the outer margin of the stipes and cardo is clothed with fine delicate hairs; the lamina is furnished on its under surface with a number of long hairs which extend over the proximal joint of the palp.

The *first ambulatory limb* presents no special differences from that of other species.

Of the *second pair* in the male, the penultimate joint is rather narrow, only slightly wider where it articulates with the preceding joint; the distal joint terminates in a spine-like extremity which is separated by a suture; just behind the articulation of this spine is a ridge bearing a row of fine hairs. The remaining joints of this limb are almost smooth, and have only a few short hairs.

The *remaining thoracic appendages*, on the contrary, are abundantly furnished with long, unbranched hairs, and short, stout, serrated, and smooth spines; the latter are especially developed at the distal extremity of each joint just before its articulation with the succeeding joint.

The proximal joint of the limb is the stoutest, and except in the two penultimate limbs, the longest, its margin is clothed with fine delicate unbranched hairs; the second joint is shorter, and the third shorter still; the fourth and fifth joints in the posterior limbs are considerably elongated; the distal extremity of the terminal joint is separated off by a suture, and ends in a sharp spine.

The *abdominal appendages* present no peculiarities except the terminal uropoda, which have been well described and figured by Studer;[1] the endopodite becomes fused with the protopodite, and is extraordinarily elongated; the short exopodite is spine-like, and can be fixed at right angles to the rest of the appendage, forming in this way a defensive apparatus, which, as Studer suggests, no doubt secures to the animal a greater freedom from the attacks of birds and other enemies. For figures and fuller description of this structure the above-mentioned Memoir by Studer should be consulted. The structure of the uropoda in this species recalls that characteristic of the family Sphæromidæ.

Two specimens of *Serolis latifrons* dredged off Possession Island in 210 fathoms present some variations from all the other specimens; they are both females, with fully developed brood lamellæ, and are approximately of the same size, measuring 28 mm. in length by 23 mm. in breadth; the proportions therefore of these specimens are nearly the same as in the males of the typical Kerguelen form; the sterna of the abdominal segments, however, are quite like those in the females. In one specimen the posterior two pairs of brood lamellæ of the left side overlap those of the right, the two anterior pairs are normal. This variety is quite different in colour, being of a uniform yellowish brown, with a few scattered black spots, especially upon the caudal shield. The shape of the caudal shield is different from that in the Kerguelen specimens; it is considerably narrower, and the lateral margins are almost straight, with only a very slight outward bulging; the posterior epimera of the body come therefore to project considerably beyond the margin of the caudal shield, which is almost completely triangular in shape.

One of the specimens is figured on Pl. II. fig. 1, and may be compared with the figures of Studer and Miers of the normal variety.

Station 148, January 3, 1874; lat. 46° 47′ S., long. 51° 37′ E.; 210 fathoms; bottom, hard ground, gravel, shells.

Kerguelen Island, January 13, 1874; Cascade Bay, 5–40 fathoms. January 17, 1874; Royal Sound, 25 fathoms.

[1] *Archiv f. Naturgesch.*, 1879.

5. *Serolis septemcarinata*, Miers (Pls., II. fig. 14, VIII. figs. 3–5).

Serolis quadricarinata, White, List Crust. Brit. Mus., 1847, p. 106.
Serolis septemcarinata, Miers, Ann. and Mag. Nat. Hist., 1875, p. 116.
Serolis septemcarinata,[1] Miers, Phil. Trans., 1879 (extra vol.), p. 206.
Serolis ovalis, Studer, Archiv f. Naturgesch., 1879, p. 24.

That *Serolis septemcarinata* is the same species as *Serolis ovalis* cannot be doubted; the descriptions and figures given by Miers and Studer agree in every detail.

Both these observers described the species from a single specimen only; Studer's description relates to a female specimen from Kerguelen, while Miers's specimen was dredged at the Crozets.

The Challenger obtained this species at Kerguelen, and also off Prince Edward's Island; the species therefore is common to these three groups of Antarctic Islands, but has not as yet been obtained elsewhere.

Studer remarks the rarity of this species as compared with *Serolis latifrons*, and suggests that the absence of the spine-like uropoda found in *Serolis latifrons* may render it an easier prey to its enemies; the Challenger, however, collected a large number of specimens of this species at Kerguelen, very nearly as many as of *Serolis latifrons*.

The males of this species differ from the females by their greater size.

The largest male specimen measures 13 mm. in length by 11 mm. in breadth, the largest female specimen measures 11 mm. in length by 9 mm. in breadth. All the specimens obtained by the Challenger, with the exception of a few newly hatched young, are almost exactly the same size as the two specimens from which the measurements are taken, and the superiority in size of the males over the females can therefore be very plainly seen.

The abdominal epimera are similar in both sexes.

A noticeable difference between the two sexes is to be found in the first thoracic epimera; the under surface of these epimera in the males is furnished with a row of ridge-like tubercles, six or seven on either side, which are situated just external to the attachment of the appendages; they are arranged in a semicircle, with the convexity directed forwards and outwards; in the female there is no trace of any such structure; it is probable that these tubercles assist the male in maintaining a firm hold of the female during copulation.

The general surface of the body, especially the epimera, is sculptured, the latter are traversed by innumerable ridges anastomosing with each other; on the cephalic shield and the tergal portion of the segments the surface is covered by minute scattered pits. All the epimera, with the exception of the first, are traversed by a crescentic ridge which

[1] In my opinion the catalogue name *Serolis quadricarinata* ought not to have been changed by Miers in spite of its being a "*nomen ineptum*," but since the actual description of the species is under the name of *Serolis septemcarinata*, it is necessary to adopt it here.

follows at some distance the anterior margin of the segment; the first epimera are not divided by any transverse suture; the epimera of the three succeeding segments are separated from their terga by a suture.

The *cephalic shield* has a crescentic ridge between and a little in front of the eyes as in *Serolis tuberculata* (*cf.* Pl. VI. fig. 1) and other species; its anterior margin is prolonged in the median line into a short rostrum, and as in other species a ridge separates off the antero-lateral portion from the rest.

The *caudal shield* is trifid at its extremity, and furnished with a central carina which runs from end to end; on either side of this are two lateral carinæ, which do not extend along the whole length of the caudal shield, they terminate behind at some distance from the end of the caudal shield in freely projecting spines; the inner pair extend farther back than the outer pair; another carina runs parallel with the anterior margin of the caudal shield on either side, and terminates close to the articulation of the uropoda. The lateral margins of the caudal shield, as well as of the posterior epimera, are denticulate. A noticeable character of this species is the prolongation of the abdominal epimera a little way beyond the last pair of thoracic epimera; in *Serolis minuta* the same thing occurs, but in these two species only.

The *first pair of antennæ* are a little shorter than the second pair; the filament, which has about eighteen joints, is rather longer than the basal portion of the antenna,—the latter is composed of four joints; the first is short, the second about twice its length, and about equal in length to the succeeding joint, though considerably stouter than it.

In the *second pair of antennæ* the two distal joints of the stem are the longest, and about equal in length to each other; they are somewhat bow-shaped, and the anterior margin is beset with tufts of long hairs, five to each joint in the specimen from which the description is taken; the filament has twelve or thirteen joints.

The *mandibles* show the usual asymmetry; the left mandible has a chisel-like cutting process, the edge of which is somewhat crenate in outline; this structure is absent from the right mandible.

The *first pair of maxillæ* consist as usual of a basal piece with which are articulated two masticatory lobes; the posterior of these is delicate and small, and bears one short spine at its expanded distal extremity as in *Serolis paradoxa* (*cf.* Pl. V. fig. 14).

The *second pair of maxillæ* are comparatively large; the middle lobe is furnished with four spines upon the cutting margin instead of the usual two.

In the *maxillipedes* the stipes and lamina are completely separated by a suture; the second joint of the palp is not so markedly heart-shaped as in other species.

In the *second pair of thoracic appendages* the sixth joint is entire; the fifth joint has a row of spines upon the inner side, they are as usual of two kinds; the longer spines terminate in a bifid extremity, of which the anterior bifurcation is the longest; the axis of the spine extends between the two branches, and is rather longer than either.

One of the *third pair of thoracic appendages* in the male is displayed in fig. 3; the spines peculiar to this limb are confined to the projecting lower angle of the penultimate joint; several of these are shown more highly magnified in fig. 5.

The remaining thoracic limbs present no features of interest.

The *third pair of appendages* in the male (Pl. VIII. fig. 3) is rather different from the same appendages in other species; the penultimate joint is comparatively long and narrow, but widens out in its posterior fourth, where six spines are attached in pairs; at the upper end, close to its articulation with the terminal joint, is a single pair of spines; the interval between this spine and the six at the hinder end of the joint is beset with a few scattered hairs; the posterior spines are broad and conical, and the central filament projects a short way out from the extremity. The remaining joints of this limb are smooth and almost devoid of spines. The other thoracic appendages (Pl. VIII. fig. 4) are all similar to each other, save that in the last pair, the third, fourth, and fifth joints are clothed with a closely set row of fine delicate hairs in addition to the sharp sword-like spines which are found here as in the other appendages; in the female these hairs appear to be absent. The same difference between the two sexes in this appendage has been already described in *Serolis convexa* (*ante*, p. 40), and it exists in other species. The terminal joints of the thoracic appendages from the third pair onwards are divided by a suture into a short distal and a long proximal half.

The *first three abdominal appendages*, like those of many other species, have the inner angle of the basal joint prolonged into a process which bears three branched hairs in the first and two such hairs in the two following pairs of appendages. The suture upon the *opercula* is inclined at an angle with the transverse axis.

The *uropoda* are attached exactly half way down the lateral margin of the caudal shield, but do not extend as far as its extremity.

Station 145, December 27, 1873; lat. 46° 43′ S., long. 38° 4′ 30″ E.; 140 fathoms; bottom, volcanic sand.

Station 149B, January 17, 1874; lat. 49° 28′ S., long. 70° 30′ E.; 25 fathoms; volcanic mud; off Marion Island, 50 fathoms.

Station 149C, January 19, 1874; lat. 49° 32′ S., long. 76° 0′ E.; 60 fathoms; bottom, volcanic mud.

Station 149D, January 20, 1874; lat. 49° 28′ S., long. 70° 13′ E.; 28 fathoms; bottom, volcanic mud.

6. *Serolis cornuta*, Studer (Pl. I. figs. 1–16).

Serolis cornuta, Studer, Beitr. zur Kennt., &c., Archiv f. Naturgesch., 1879, p. 19.

This species has been described by Studer in his Memoir on the Fauna of Kerguelen,[1] where a figure is given of the male and certain of the appendages. The males and

[1] *Loc. cit.*, pp. 21–24.

females differ from each other in their shape; as in *Serolis schythei*, the male is much broader in proportion to its length, being nearly circular in outline; in the female the shape of the body is oval; this difference depends upon the greater length of the epimera; in the male the sixth pair extend nearly so far as the end of the terminal spine of the caudal shield, while the two abdominal epimera extend about half way down the caudal shield, their posterior extremities being situated on a line with the articulation of the uropoda; in the female the sixth thoracic epimera only just pass beyond the articulation of the uropoda, while the abdominal epimera hardly reach as far.

The sterna of the abdominal segments differ in the two sexes; in the male the two first are oblong in shape, the posterior margin being slightly concave, the third is prolonged into a flat triangular spine; in the female the posterior margin of all the segments is prolonged into a blunt spine; the length of these increases progressively from before backwards.

Studer has given a good general description of this species, comparing it with *Serolis trilobitoides*, to which it is most nearly allied. For the sake of completeness I give here a recapitulation of his description, with a few additions, which applies to all the specimens in the Challenger collection, the variations being inconspicuous and confined to the colour, which is darker or lighter, and the number of spines upon the carina of the caudal shield, which vary from three to six.

The length of the largest male specimen is 34 mm., its breadth 31 mm.; the length of the largest female specimen is 41 mm., its breadth 35·5 mm.

The length of the *cephalic shield* is about one-fifth of the whole length of the body; close to the anterior margin is a transverse ridge which runs almost parallel to it; in front of the eyes, and occupying the middle of the cephalic shield, is a squarish area raised and separated off by a groove; the posterior margin of this is slightly concave, the two ends being somewhat produced backwards; the lateral portions of the cephalic shield in front of the eyes slope gradually downwards towards the side; behind and to the inside of the eyes is a large blunt conical tubule, one on either side; between the two, and forming the posterior boundary of the cephalic shield, is a flattened triangular area.

Thorax.—The epimera are broad and sickle-shaped, and the terminal portions from the articular process outwards project freely and do not overlap each other; the articular processes are short, and as in many other species, there are only two to each epimeron; the posterior articular process of each epimeron overlaps the anterior articular process of the succeeding epimeron.

The second, third, and fourth epimera are separated from their terga by a distinct suture. The anterior epimera are separated into two halves by a transverse ridge, and there is in addition an anterior ridge as in *Serolis bromleyana* and *Serolis gracilis*, which is a continuation of the anterior ridge on the cephalic shield; it runs at first parallel to the anterior margin of the epimeron at some little distance from it, and then bends

abruptly at right angles, terminating a little way in front of the second transverse ridge. The margins of all the epimera are minutely serrated externally. The terga of the free thoracic segments have almost the same antero-posterior diameter, the two last being only a trifle narrower; the sterna of the first two thoracic segments are as usual divided by sutures into a median and two lateral sclerites; the median sclerite of the anterior segment is keeled, that of the second has a short keel, widening behind and extending over its anterior half only. The posterior margin is raised into a ridge, which is continued along the lateral sclerites, but is here rather narrower. The sterna of the three last segments are partly fused as in other species.

Abdomen.—The caudal shield is rather more than one-third of the length of the whole body; its shape is pentagonal, and the end is produced into a long spine; there is a distinct longitudinal keel, which is furnished with three to six short recurved spines, the first of which is always the largest; at the anterior end of the caudal shield are two short spines, one on either side, and closely approximated to the middle line; from the outer margin of each of these runs a fold somewhat curved in its course, which terminates a little in front of the attachment of the uropoda in a short spine; this lateral fold is similar to that found in *Serolis paradoxa* and *Serolis schythei*, and perhaps marks the boundary of the last segment of the abdomen; the lateral margins from the attachment of the uropoda to the terminal spine are provided with a number of small teeth.

On Pl. I. are figures of a male (fig. 1), female (fig. 2), and an immature male specimen (fig. 3); the latter is introduced in order to show its similarity in shape to the female (see p. 27).

The first pair of *antennæ* are shorter than the second pair by about half their own length; the terminal joint of the base is large, being rather more than half as long as the preceding joint; the filament, which is about as long as the rest of the antenna, has twenty-five joints.

In the second pair of antennæ the basal portion has as usual five joints, of which the last is the longest, being about equal in length to both the third and fourth joints together. The filament is nearly but not quite as long as the fifth joint, and is composed of fifteen or sixteen joints. One of these is shown highly magnified in Pl. I. fig. 6; on the inner and lower surface of some of the joints towards the middle of the filament is a row of short lancet-shaped spines; these decrease in size towards the distal end of the filament, and in the last three or four joints seem to be entirely absent; they commence to be visible on about the third joint of the filament, but are only present in small numbers towards the distal end of the joint and close to its articulation with the one in front. The figure (Pl. I. fig. 6) represents the seventh joint; these spines, which are present upon the antennæ of both sexes, are like those that are found in *Serolis paradoxa*, and which have been described (*ante*, p. 35).

Mandibles.—The distal extremity of the right and left mandibles of a male specimen

of *Serolis cornuta* are shown on Pl. I. figs. 7 and 8. The right mandible (fig. 7) has upon the upper surface a broad chisel-like process which is absent from the left; the latter is compensated by two large bifid spines instead of the single spine which springs from the lower surface of the right mandible. In another specimen, however, these conditions were reversed, the chisel-like plate being developed only upon the left mandible, while the right mandible had two spines.

The *first pair of maxillæ* are quite like those of other species.

The *second* pair (Pl. I. fig. 9) in one specimen were asymmetrical like the mandible; the middle lobe of the left hand maxilla had four spines, while the right hand one (Pl. I. fig. 10) had only two; in another specimen, however, both right and left maxillæ had only two spines.

The *maxillipedes* (Pl. I. fig. 11) are very much covered with hairs; the stipes, which is separated from the lamina by a complete suture, is squarish in outline; the palp is broad and flat, the second joint distinctly cordate in outline.

The *second pair of ambulatory limbs* in the male is modified in the usual way; a single spine similar to those which are found upon the inner margin of the penultimate joint of these appendages is also found on the inner side and close to the distal end of each of the two preceding joints.

The remaining ambulatory limbs are in no way remarkable; they are more like those of *Serolis schythei* than any other species; the first joint is the longest and broadest; the second joint is narrower and slightly shorter; it increases in width towards the distal extremity, which is furnished with a tuft of comparatively delicate spines and hairs; the third and fifth joints are subequal in size, while the fourth is a trifle longer; large sword-like spines mingled with smaller ones, and a very few serrated spines, are arranged in tufts on the inner and outer sides of the distal extremity of these joints, and a few along the outer margin.

The *three anterior abdominal appendages* of the female are displayed in figs. 12–14 of Pl. I.; as in *Serolis septemcarinata* and others the basal joint of the first (fig. 12) has three branched hairs like those which clothe the outer margin of the exopodite and endopodite of the same appendages, but smaller; the second and third of these appendages (figs. 13, 14) have two hairs instead of three.

The suture upon the exopodite of the fourth pair of abdominal appendages is oblique.

The *uropoda* are attached about half way down the caudal shield, and extend as far as its termination, the exopodite does at least, being almost half again as long as the endopodite; the outer margins of both, and the distal extremity of the inner margin are serrated and beset with branched hairs.

Station 149, January 9, 1874; lat. 49° 8′ S., long. 70° 12′ W.; 25 fathoms; bottom, volcanic mud. January 13, Betsy Cove, Kerguelen Island.

Station 149B, January 17, 1874; lat. 49° 28′ S., long. 70° 30′ W.; 25 fathoms; bottom, volcanic mud.

Station 149D, January 20, 1874; lat. 49° 28′ S., long. 70° 13′ W.; 28 fathoms; bottom, volcanic mud.

Station 149E, January 21, 1874; lat. 49° 37′ S., long. 70° 16′ W.; 30 fathoms; bottom, volcanic mud.

Station 149K, January 29, 1874; lat. 48° 40′ S., long. 69° 6′ W.; 45 fathoms; bottom, volcanic mud.

7. *Serolis bromleyana*, Suhm (Pl. IV.).

Serolis bromleyana, v. Willemoes Suhm, Proc. Roy. Soc. Lond., vol. xxiv. p. 591, 1876.
Serolis bromleyana, Challenger Briefe, No. II., Zeitschr. f. wiss. Zool., Bd. xxiv. p. xix., 1874.

This species, which is considerably the largest of the genus, has been already briefly characterised by the late Dr. v. Willemoes Suhm from two specimens dredged in 1975 fathoms near the Antarctic Ice-Barrier. The following description is taken from these specimens:—Length of male 54 mm., greatest breadth (at the level of the third epimera) 56 mm.; length of female 45 mm., greatest breadth 39 mm.

The male differs from the female by its greater size and in the greater length of the epimera; in both sexes the length of the thoracic epimera gradually increases up to the sixth, which are by far the longest, and extend for a considerable distance behind the termination of the caudal shield. The extreme length of these epimera, measured from their articulation with the epimera of the preceding segment, is 47 mm. in the male and 33 mm. in the female. The epimera of the second and third abdominal segments project beyond the caudal shield in the male; in the female the last pair barely reach as far as its termination. The form of the sterna of the free abdominal segments does not differ at all in the two sexes.

The outline of the body is more or less oval, and the great length of the epimera, which become extremely narrow and spiniform towards their end, serves to distinguish this species from all others, with the exception of *Serolis neœra* and *Serolis grâcilis*. From both these species, however, it can readily be separated by numerous other points of difference. The body is covered with scattered hairs, which are especially developed upon the sides of the epimera. The colour (in alcohol) is violet-grey with whitish yellow patches upon the caudal shield and posterior portion of the thorax; the colour of the living animal is described by v. Willemoes Suhm as being of "a fine blue colour with a red spot extending over the midst of the body and the eyes."

Cephalic Shield.—The shape of the cephalic shield can be understood by a reference to Pl. IV. fig. 1; it is longer than broad, owing to the projection of its lateral portions for some way in front of the rostrum; these antero-lateral portions of the cephalic shield

are separated from the rest by a ridge which runs from just below the rostrum to the lateral margin on either side; the whole cephalic shield is very distinctly separated from the thoracic segment by a deep furrow; the central portion which lies between the eyes is very strongly convex, and separable into three regions—two round convexities which lie to the inner side of and behind each eye, and a median T-shaped elevation, at the upper end of which, on a level with the anterior portion of the eyes, are four tubercles arranged in a semicircle with the concavity directed forwards; at the hinder extremity is another short tubercle; the whole surface of the cephalic shield, with the exception of a flattened area which extends from the upper end of the eyes to the transverse ridge, is covered with minute pit-like depressions. The eyes are whitish yellow in colour.

Thorax.—The thoracic segments, like the cephalic shield, are covered with an immense number of irregular pit-like depressions; the posterior margin of each segment is furnished with a minute tubercle. The epimera are of great length, and increase gradually from the first up to the sixth and last pair.

The epimera of the first thoracic segment are as usual large and expanded, but narrow rapidly towards the distal extremity, which is narrow and spine-like as in the succeeding segments. The anterior margin of these epimera bears a short forwardly directed spine at about 3 mm. distance from the cephalic shield. The epimeron is divided into three pieces by a Y-shaped ridge; the two arms of the Y form a very obtuse angle, one is continuous with the anterior spine already referred to, and the other passes outwards towards the distal end; the unpaired arm seems to correspond to the suture which is often developed upon the first pair of epimera in other species. The two areas lying respectively in front of and behind this median ridge are somewhat concave, while that portion which lies to the outside of the arms is convex.

The epimera of the three succeeding segments are curved and sickle-shaped, and project outwards at a greater angle with the longitudinal axis of the body than the rest, which by degrees come to lie almost in the same straight line with this axis. A distinct suture separates the dorsal portion of the three anterior free thoracic segments from these epimera. All the epimera of the body project downwards as well as outwards, especially in the male specimen, so that when the animal is placed upon a flat surface, the body rests entirely upon the epimera. The second of the free thoracic segments is the widest, and measures 4·5 mm. in diameter; the first and third are a trifle smaller, while the fourth and fifth are only one-third of the diameter of the second.

The sterna of the two first thoracic segments are divided by sutures into three portions, a median and two lateral. The median portion of the anterior segment (that which bears the maxillipedes) is keeled; the sterna of the second, third, and fourth segments are divided by a median suture into two equal halves; the remaining segments have a rather peculiar arrangement, which is displayed in Pl. IV. fig. 2; the middle portions of the three segments are fused together to form a somewhat oval plate, divided by a median

suture, and upon which two transverse furrows mark the boundary between the several segments of which it is composed. The lateral portions of the sterna of the three segments are at first fused together, but become separate just before the attachment of the appendages; and a triangular plate with the apex directed posteriorly, lies between the median and lateral portions of the sternum of the sixth segment.

Abdomen.—The first abdominal segment has as usual no epimera; its width is about double that of the preceding thoracic segment; the second and third abdominal segments are long and well developed, and terminate in a somewhat bifid extremity, the inner limb of the bifurcation being considerably longer than the outer (figs. 1, 2). The sterna of the three free abdominal segments are shown in fig. 2; there is a short median backwardly projecting tubercle, longer in the second and third than in the first; this is continuous with a longitudinal ridge which is crossed at right angles by another ridge. The male and female specimens, as already mentioned, show hardly any differences in the conformation of these abdominal sterna; in the female the antero-posterior diameter is somewhat less, and the median tubercle somewhat more pronounced than in the male.

The *caudal shield*, which is broader than long, has a somewhat pentagonal contour with rounded angles; the uropoda are attached about half way down the side, the posterior extremity is notched and rather turned up; there is a median longitudinal keel, and on either side a short flat spine near the lateral margin, and on a level with the attachment of the uropoda; the surface between the keel and these spines is almost flat, but is strongly bent downwards; the length of the caudal shield in the male is 17 mm., almost half that of the rest of the body, its breadth 21 mm.

Appendages.—The *antennæ* are almost exactly of the same length. The first pair of antennæ has four joints and a terminal filament made up of thirty-one joints, and equal in length to the first four joints.

The basal joint is oval, with a truncated distal extremity; the second joint slightly longer, with a straight outer and convex inner margin; the third joint is half again as long as the second and about half its width; it is cylindrical in shape; the terminal joint is about one-third of the length of the preceding joint, and of the same shape.

The second pair of antennæ have six joints and a short terminal filament; the sixth joint is the longest, the third is slightly longer than the fourth; the two basal joints are small, especially the second, which only occupies one side of the antennæ, on the other (inner) side the first joint articulates directly with the third; on the fourth, fifth, and sixth joints are a series of ridges running transversely to their long axes, and bearing bunches of fine hairs.

The *mandibles* are as usual asymmetrical; the left hand one has a projecting chisel-shaped process which is wanting in the right hand one.

The *maxillæ* are like those of other species; the anterior pair has nine or ten curved spines upon the cutting edge, the most anterior of which appear to be the largest.

In the *maxillipedes* (fig. 8) the stipes and lamina are not separated by a complete suture.

The second pair of thoracic appendages in the male are modified like those of all other species; the inner side of the second, third, and fourth joints is clothed with fine delicate hairs (Pl. IV. fig. 6) similar to those of *Serolis neœra*, but more delicate and inconspicuous; these structures I was only able to find in some of the specimens from Stations 168 and 169; in the large specimen from Station 156 (*cf.* Pl. IV. fig. 5) they are certainly not present, nor in the single specimen from Station 164A. It does not appear quite certain whether the presence or absence of these hairs is merely a local variation or an indication of a dimorphism in the males of this species analogous to that which Fritz Müller[1] has described in a species of *Tanais*.

The remaining thoracic appendages are slender, like those of *Serolis gracilis*, and, as in that species and others, the fourth joint is longer than the third or fifth joints; the hairs and spines are also small and delicate; neither the serrated spines found in many species nor the pinnate hairs found in *Serolis neœra* and *Serolis gracilis* seem to occur in this species; at the distal end of the penultimate joint only are there very long slender hairs, many of which are considerably longer than the terminal joint of the appendage.

The *abdominal appendages* are like those of *Serolis antarctica*.

The operculum is divided by a transverse suture at right angles to its longitudinal axis.

The *uropoda* are comparatively small, and attached at the commencement of the posterior third of the caudal shield.

Variations.—The description just given refers to two specimens dredged at Station 156; this species was also obtained at three other Stations, viz., Stations 164c (400 fathoms), 168 (1100 fathoms), and 169 (700 fathoms), and some of the specimens show certain differences, chiefly in the length of the posterior thoracic epimera and in the conformation of the two abdominal epimera; in one specimen (Pl. IV. fig. 3) the posterior thoracic epimera, instead of lying nearly parallel to the long axis of the body, are curved inwards towards the extremity so as to partly enclose the caudal shield; in this specimen the last thoracic epimera are proportionately longer than in the type specimen, measuring 36 mm. as against 35 mm. length of body, whereas in the type specimen these epimera, as already stated, measure 47 mm., the length of the body being 54 mm. In the majority of specimens the abdominal epimera terminate in a sharp point and are not notched at their extremity; two other specimens, however, had abdominal epimera precisely like those figured on Pl. IV. fig. 1, and since both these specimens are small, not measuring more than half the length of certain other specimens in which the abdominal epimera terminate simply in a point, this character cannot be looked upon as peculiar to adults.

In all the specimens obtained at Stations 168 and 169, the ridges upon the cephalic

[1] Für Darwin (Facts for Darwin), English translation, London, 1869, p. 19 *et seq.*

shield are somewhat different from those figured and described in the type specimens; a strong ridge runs parallel to the outer margin of the epimera; at its upper extremity it bends backwards and passes for a short distance parallel to the boundary line of the cephalic shield, terminating a little below the ridge which crosses the latter; the transverse ridge, which indicates the division of the epimeron into two parts corresponding to the first two thoracic segments, is very slight; the anterior spine-like process of these epimera is not present, and the anterior margin is in consequence quite smooth (fig. 3). Many of these specimens are more darkly coloured.

In a small specimen from Station 164c (400 fathoms), measuring 16 mm. in length, the outer ridge upon the anterior epimera is not present, but the abdominal epimera have the same characters as those of the type specimens.

Station 156, February 26, 1874; lat. 62° 26′ S., long. 95° 44′ E.; 1975 fathoms; bottom, Diatom ooze.

Station 164c, June 13, 1874; lat. 34° 19′ S., long. 151° 31′ E.; 400 fathoms; bottom, green mud.

Station 168, July 8, 1874; lat. 40° 28′ S., long. 177° 43′ E.; 1100 fathoms; bottom, blue mud.

Station 169, July 10, 1874; lat. 37° 34′ S., long. 179° 22′ E.; 700 fathoms; bottom, blue mud.

8. *Serolis necæra*, F. E. B. (Pl. V. figs. 1–11).

Serolis necæra, F. E. Beddard, Proc. Zool. Soc. Lond., 1884, pt. iii. p. 331.

This species almost rivals *Serolis bromleyana* in size, and resembles it in the great length of its spiniform epimera.

The largest male measures 42 mm. in length and 48 mm. in breadth; the largest female measures 41 mm. in length and about 40 mm. in breadth. The difference in the proportion of length to breadth in the two sexes is caused by the greater development of the epimera in the male; the two sexes also differ in the characters of the sterna of the abdominal segments and in the frontal "sense organ," which is much larger and more evident in the female (*cf.* figs. 1 and 3); there is not such a marked difference between the lengths of the abdominal epimera in the two sexes as is often found in the other species of *Serolis*.

Cephalic Shield.—The eyes are unusually large and conspicuous, 6 mm. long, bluish black in colour owing to the comparatively small amount of pigment present; the diameter of the cephalic shield is greater than its length; as in *Serolis bromleyana*, a transverse ridge passes from the base of the rostrum to the lateral margins of the cephalic shield, and cuts off a small antero-lateral portion; the anterior margin of this as well as of the first epimera is bent upwards. Between the eyes are a number of spiniform pro-

cesses which are hollow and filled up with connective tissue, two smaller median spines and two outer ones with a bifid extremity; the posterior margin of the cephalic shield is indented, and forms three projections, the two outer ones being somewhat triangular in shape, and tuberculated on the free margin, while the inner median one is transversely elongated, and much like the labium in shape, with a slightly convex outer margin.

Thorax.—Each of the thoracic segments is furnished with a median spine—the first three are considerably longer than the rest; the antero-posterior diameter of the thoracic segments increases from the first to the fourth, the latter measuring 3·5 mm. in the male; the two last thoracic segments are comparatively longer than in *Serolis bromleyana*, rather more than half as long as the preceding segment. The terga of the three anterior free thoracic segments are separated from their epimera by a distinct suture. The epimera of the segments gradually increase in length up to the sixth pair, which are extremely long, measuring 37 mm. in the male, and extend backwards in a direction nearly parallel to the long axis of the body.

The first epimera are larger in the male than in the female (*cf.* figs. 1, 3); in the latter the margin of the epimera passes at first abruptly backwards, and then curves outwards; the antero-lateral portion of the cephalic shield projects outwards beyond the commencement of the epimeron for a short space, and ends in a truncated slightly notched extremity; in the male the outer margin of the first pair of epimera is quite regular. The epimera are divided into two halves by a longitudinal ridge.

The sterna of the two anterior segments are as usual divided by sutures into three sclerites; the anterior segment is similar in shape to that of *Serolis bromleyana;* the median sclerite of the second segment is saddle-shaped as in the last mentioned species, but instead of being smooth the anterior half is produced downwards into a triangular process; the posterior half is raised into two knobs, which are separated from each other in the median ventral line by a suture. The three succeeding segments are divided by a median suture which is continuous to the end of the thoracic segments. The sixth, seventh, and eighth thoracic segments are entirely similar to those of *Serolis bromleyana* above described.

Abdomen.—The epimera of the second abdominal segment extend for a space of about equal to half its own length beyond the caudal shield; they are not perceptibly longer in the male. The epimera of the third segment are very short, and only extend to about the commencement of the lateral margin of the caudal shield; the length of these epimera also does not differ in the two sexes. The posterior extremity of the first pair of these epimera is notched as in *Serolis bromleyana.* The sterna of the three free abdominal segments differ in the two sexes; in the female the posterior margin of each is produced into a short spine, the first being the largest and longest; in the male the last of the three segments only has a spine.

The *caudal shield* is almost hexagonal in outline; its length in both the male and female is about 11 mm.; it is therefore smaller in proportion than that in *Serolis bromleyana;* its breadth is about 12 mm. The urqpoda are attached at about the commencement of the posterior fourth. The median portion of the shield is slightly keeled, and bears two spines one in front of the other, the posterior being the larger of the two. On either side are two other short flat spines. The caudal shield of this species is very similar to that of *Serolis schythei,* but it is not so distinctly carinate, and the anterior median spine is flatter and not so large as in *Serolis schythei,* while the posterior median and the lateral spines are larger than in that species.

Appendages.—The second pair of antennæ are a little longer than the first pair.

In the *first antennæ* the two basal joints are of about equal length, the third joint is twice as long as either of the preceding ones, the fourth joint short, hardly longer than the first joint of the filament; the filament is composed of about twenty joints.

The *second pair of antennæ* have the third, fourth, and fifth joints as usual covered on the inferior surface with tufts of hairs in groups of three or four; the filament has some fifteen joints.

The *mandibles* do not appear to differ from those of other species.

The *first maxillæ* consist as usual of a stout elongated lobe and small oval lobe, both of which articulate with the cardo; the smaller lobe is furnished on the free cutting edge with a single spine as it is in *Serolis paradoxa* (*cf.* Pl. V. fig. 14).

The *maxillipedes* are figured on Pl. V. fig. 6; the suture between the lamina and stipes is complete; the palp of the mandible is abundantly furnished with setæ, and the second joint has on the inner side the small protuberance characteristic of all the deep-sea species of the genus (*a*).

The *second pair of thoracic appendages* differ from those of other species in that the hairs which clothe the inner margin of the penultimate joint are very similar in form; several of these are shown on Pl. V. fig. 7; the longer hairs (*a*) only differ from the shorter ones (*b*) by the proportions of their length and breadth.

The *third pair* (fig. 8) are as usual modified into a prehensile organ in the male; the third, fourth, and fifth joints are covered on the inner side with a dense row of hairs which are shown magnified in fig. 9, *a'*; these hairs are clothed on the distal half with fine branches, and they closely resemble the hairs that are found on the second thoracic appendage of the males of *Serolis convexa.* The fifth joint is oval, narrowing towards the upper extremity; it possesses the peculiar spines characteristic of this appendage; they are narrow and cylindrical, and terminate in a long thread which is given off from the upper surface of the spine just before its termination (fig. 9, *b'*). The sixth joint is divided by a suture into a small distal portion and a long proximal portion.

The *ambulatory limbs* differ from those of other species in the character of the hairs; instead of sharp serrated spines, which are generally developed upon these appendages, the ambulatory limbs of *Serolis neœra* are clothed with long branched hairs similar to those found upon the three anterior abdominal appendages, but somewhat shorter. One of the limbs of the right side is figured on Pl. V. fig. 10; the other thoracic limbs hardly differ at all, except that the last is considerably shorter as in other species. On the inner margin of the proximal joint are a number of very fine hairs, the distal half being furnished with delicate branches. These hairs are exactly similar to the terminal hair of the first antennæ in this and other species, and are possibly sensory. The remaining joints are provided with bunches of branched hairs, those on the inner side of the limb being longer than those on the outer side; the arrangement of these can be seen by an inspection of the figure (fig. 10); the terminal joint forms as usual a claw which is long and slender.

Abdominal Appendages.—These appendages present no peculiarities; the basal joint of the first pair is furnished with three hairs upon the inner posterior angle. The two following appendages have each two hairs in the same place.

The exopodite of the first pair of gills is divided by an oblique suture, and the endopodite is bifid at the tip (see fig. 11).

Another specimen of this species which was dredged in 2040 fathoms (Station 318) is in some respects different, but the differences do not appear to me to be of sufficient importance to warrant its separation as a distinct species.

The epimera, instead of being long and spiniform as in all the other specimens contained in the Challenger collection, are comparatively short, and resemble the epimera of the typical shallow-water forms (*e.g.*, *Serolis schythei*) in being comparatively wide and flattened; the two posterior thoracic epimera were unfortunately broken off on both sides of the body, but judging from what remains it seems very likely that the sixth pair at any rate extend back beyond the termination of the caudal shield. The anterior pair of abdominal epimera terminate a little way in front of the attachment of the uropoda.[1]

Station 318, February 11, 1876; lat. 42° 32′ S., long. 56° 29′ W.; 2040 fathoms; bottom, blue mud.

Station 320, February 14, 1876; lat. 37° 17′ S., long. 53° 52′ W.; 600 fathoms; bottom, green sand.

[1] This specimen was mounted on a slide in glycerin; on the same slide, entangled with the appendages of the *Serolis*, were several small Nematodes, not sufficiently well preserved to exhibit any distinctive generic character. It is of course not certain that they came from the same depth as the Crustacean, but, bearing in mind the fact that many of the marine free-swimming Nematoidea attach themselves in a semiparasitic fashion to other animals (*cf.* Villot, Arch. d. Zool. Exp., t. iv. p. 451, 1875), it is at any rate possible; so little is known respecting the distribution of the free-swimming Nematoidea that I think it worth while to record this fact, especially as I observed other Nematoidea among the appendages of one of the specimens of this same species from Station 320.

9. *Serolis gracilis*, F. E. B. (Pl. III. figs. 7–13).

Serolis gracilis, F. E. Beddard, Proc. Zool. Soc. Lond., 1884, pt. iii. p. 332.

Five specimens of this species were dredged at Station 120 (675 fathoms), three males and two females.

The males were approximately of the same size, the largest measuring 21 mm. in length by 22 mm. in breadth; the females were much smaller, measuring 9 mm. in length, by 8 mm. in breadth.

The chief difference between the two sexes, apart from that of size and relative proportions of length and breadth, consists in the greater length of the epimera in the males; in the female specimens (Pl. III. fig. 8) the last thoracic epimera hardly reach as far as the end of the caudal shield, while the first abdominal epimera only extend about half way down, and the posterior abdominal epimera terminate at about the level of the end of the anterior third of the caudal shield; in the male (Pl. III. fig. 7) the posterior thoracic epimera are considerably longer, reaching beyond the caudal shield for a space of about its own length; the actual length of these epimera is 13 mm.; the first abdominal epimera extend a short way beyond the end of the caudal shield, and the posterior pair to about the middle. The difference between the two sexes in the length of the epimera is more marked in this species than in any other known to me.

The general form of the body is circular, and the dorsal surface is covered with scattered pits; the colour (in alcohol) is a dark slate-blue, varying to reddish yellow upon the terga of the posterior thoracic and abdominal segments.

The *cephalic shield* has much the same shape as in *Serolis bromleyana*; the portion lying between the eyes, which are small and inconspicuous, is strongly convex, while the antero-lateral areas are flat and depressed, and do not rise above the level of the first thoracic epimera; a transverse ridge running from the base of the rostrum, which is very minute, divides the cephalic shield as in *Serolis bromleyana*.

Thorax.—The first epimera are divided into three portions by two transverse ridges; the anterior one is continuous with the ridge that traverses the cephalic shield, it passes at first across the epimeron and then bends backwards running parallel with the anterior margin of the epimeron, and joins the distal end of the second ridge; the continuation of these two ridges passes along the margin of the epimeron closely applied to it, and terminates some way in front of the end of the epimeron. The posterior ridge corresponds to the line of suture between the two fused epimera of the first and second thoracic segments.

The other epimera are flat and sickle-shaped, not spiniform as in *Serolis bromleyana* and *Serolis neœra;* they gradually increase in length up to the sixth; the articular processes, which unite together the succeeding epimera, are placed further than is usual from the junction between the terga and the epimera, which gives the latter the appear-

ance of being shorter than they really are; the fourth and fifth as well as the three anterior epimera are separated from the terga by a distinct suture. The antero-posterior diameter of the three anterior free thoracic segments gradually increases from the first to the third; the diameter of the fourth and fifth is rather more than half that of the third. The sterna of the two first thoracic segments are as usual divided by lines of suture into three portions; the median sclerite of the first segment is keeled, and that of the second segment has a median keel which bifurcates posteriorly; the hinder half of this sclerite is divided by a median suture continuous with that which separates the right and left halves of the sterna of the succeeding segments. As in *Serolis bromleyana* and *Serolis neœra*, the median portions of the sterna of the last three thoracic appendages are fused, though the lines of division corresponding to the three segments are more strongly marked in this species than in the two above mentioned.

Abdomen.—The epimera of the abdominal segments have been already described (*ante*, p. 13); the sterna do not appear to differ in the two sexes. The *caudal shield* is squarish in outline, 7 mm. in length by 8 mm. in breadth; its length is therefore not quite one-third of that of the whole body. The uropoda are attached close to its posterior margin. There is a slight longitudinal median keel, which is crossed at right angles by a sinuous ridge with three convexities, one median and two lateral, which correspond to the spines on the caudal shield of *Serolis neœra* and *Serolis schythei*; at about the end of the anterior third of the caudal shield is a short flat spine in the middle line and two oblique ridges, one on either side of this spine; the lateral portions of the caudal shield are bent down.

The two pairs of *antennæ* are of about equal length. In the anterior pair the first joint is short and oval; the second joint is a little longer, and the upper margin projects a little way beyond the articulation of the succeeding joint, which is nearly twice its length, narrow, and bent downwards. The filament has fourteen joints.

The two distal joints of the basal portion in the second antennæ are furnished with hairs arranged in tufts along the upper margin. The filament has twelve joints.

In the *maxillipedes* (Pl. III. fig. 10) the stipes and lamina are not separated by a complete suture; the second joint of the palp has a small tubercle near the base covered with hairs as in the other deep-sea species.

The *third thoracic appendages* in the male resemble those of *Serolis neœra* in that the inner margin of the third and fourth joints bears a number of delicate plumose hairs; a few are also to be found at the upper extremity of the second joint; the penultimate joint is swollen and considerably broader at the base; the inner margin has about a dozen pairs of conical papilla-like spines which grow longer and narrower towards the distal extremity, where they come to resemble exactly the plumose hairs upon the anterior joints.

The *ambulatory limbs* are rather slender, and the joints elongated; the fourth is always longer than either the preceding or succeeding joint; the spines upon these appendages are not very much developed; the second and third joints in all bear a few pinnate hairs upon the inner margin close to the articulation with the succeeding joint; the remainder of the limb is furnished with delicate sword-like spines arranged in tufts upon the inner side; mixed with these are a few strong serrated spines which are most abundant upon the distal extremity of the penultimate joint. The inner side of the third, fourth, and fifth joints in the last ambulatory limb (Pl. III. fig. 11) is covered with soft pinnate hairs (fig. 12), like those found on the second pair of thoracic appendages of the male, and the inner side of the first ambulatory limb is similarly provided with these hairs, though to a less extent.

The *three anterior abdominal appendages* are like those of other species; the basal joint is prolonged outwards, and bears two to three branched hairs at the tip.

The suture which divides the exopodite of the opercula is oblique; the exopodite of the gill appendage is bifurcate.

Station 120, September 9, 1873; lat. 8° 37′ S., long. 34° 28′ W.; 675 fathoms; bottom, red mud.

10. *Serolis antarctica*, F. E. B. (Pl. III. figs. 1–6).

Serolis antarctica, F. E. Beddard, Proc. Zool. Soc. Lond., 1884, pt. iii. p. 333.

The three species above described agree with each other and differ from all other known species of the genus in the great development of the epimera. *Serolis antarctica*, the only other deep-sea form, has comparatively short, flat epimera as in the shallow-water species of *Serolis*. This species may be distinguished by the entire absence of eyes, and by the strongly marked sculpturing upon the dorsal surface of the body.

The Challenger collection contains eight specimens besides some fragments. The four male specimens are all approximately of the same length, the largest measuring 33 mm. in length by 31 mm. in greatest breadth. The remaining specimens, which are females, vary in size; the largest measures 31 mm. in length by 26 mm. in greatest breadth. The males, therefore, appear to be larger than the females, and also broader in proportion to their length; the contour of the body in the males is oval, in the females somewhat pear-shaped (*cf.* Pl. III. figs. 1, 3); the epimera are proportionately longer in the males, those of the sixth pair project a little way beyond the end of the caudal shield; the abdominal epimera are much the same length in the two sexes, and reach about half-way down the caudal shield; in the female the sixth thoracic epimera do not project beyond the caudal shield; the second pair of abdominal epimera are a trifle longer than the anterior pair, and both are very slightly shorter than the abdominal epimera in the male. The sterna of the abdominal segments do not seem to differ in the two sexes. The colour of this species (in alcohol) is violet-blue, inclining to reddish yellow in the middle of the body. The body has a nacreous glitter when seen by oblique light.

Cephalic Shield.—The cephalic shield is very slightly raised above the general surface of the body; its posterior surface is furnished with a short blunt tubercle; a slight ridge separates the antero-lateral portions from the rest, as in other species. The eyes are entirely absent, their place being occupied by a small tubercle similar to the rest of the chitinous integument, and containing no traces of any optic structures.

Thorax.—The dorsal surface of the thorax, as well as the rest of the body, is very much sculptured, more so than in any other species of the genus; upon the epimera the sculpturing takes the form of a network of ridges enclosing irregularly shaped roundish pits; the anterior half of the cephalic shield is sculptured in a similar fashion; the posterior part of the cephalic shield and the terga of the thoracic segments (especially upon their posterior portions) are covered with thicker ridges anastomosing irregularly; these are most conspicuous upon the lateral portions of the terga of the three anterior free thoracic segments. The sculpturing upon the terga of the abdominal segments is very slight. The sculpturing upon the caudal shield differed in different specimens; in some it resembled that of the epimera, in others the central portion between the median and lateral carinæ was occupied by a number of roundish irregularly scattered tubercles.

The posterior margin of all the thoracic as well as the abdominal segments is prolonged in the median line into a short blunt tubercle; these are larger upon the two last thoracic and the abdominal segments.

The first epimera are not divided into two portions by a suture; the succeeding epimera are closely applied to each other, the extreme end alone projecting freely; they are rather different in shape from what is customarily found in *Serolis;* instead of rapidly narrowing towards the free extremity and terminating in a fine point, the anterior margin runs parallel to the posterior margin of the previous epimeron until just before the termination of the latter, when it passes abruptly backwards in a direction nearly parallel to the long axis of the body, and joins the posterior margin almost at right angles. The fifth and sixth epimera are more like those of other species.

The epimera of the three anterior free thoracic segments are separated from the terga by a suture.

The sterna of the first two thoracic segments have the usual form (Pl. III. fig. 4); the median sclerite of the first segment is keeled, that of the second segment has a short keel extending from the anterior extremity to about the end of the first third. The sterna of the three posterior thoracic segments are similar to those of the last described species (*cf.* Pl. III. fig. 2); the male genital pores are very closely approximated in the middle line.

One of the male specimens presents an abnormality in the presence of a pair of ovigerous lamellæ upon the third free thoracic segment; the lamella of the right side was about twice as large as that upon the left side.

Abdomen.—The three anterior abdominal segments have been already described; the

caudal shield measures 12 mm. in length by 12 mm. in greatest breadth in the male specimen, and 11 mm. in length by 11 mm. in breadth in the female; it is therefore more than one-third of the length of the animal; its shape is more or less hexagonal; the lateral portions are strongly bent down, and the uropoda come to be attached quite on the under surface, and are almost invisible from above; there is a median longitudinal keel which bifurcates at about the end of the anterior fifth, on either side is a Y-shaped keel inclined at an oblique angle; the portion of the caudal shield which lies between the median and lateral keels is flat, the part which lies outside the inner fork of the lateral keel is bent downwards; the posterior end of the caudal shield is slightly bent up.

Antennæ.—In the anterior pair the two first joints are short and about equal in size; the third joint is narrow and long, twice the length of either of the preceding joints; the fourth joint is very short; the filament has about twenty-eight joints, each of which has two sensory hairs; the filament is nearly as long as the basal portion of the antenna.

The second pair of antennæ are longer; the filament has about twenty-one joints, and is almost exactly equal in length to the last joint of the basal half of each of the antennæ.

The *mandibles* are like those of other species in being asymmetrical; the left bears on the upper surface a chisel-like process and above a single spine; the right has two spines.

The upper lobe of the *first pair of maxillæ* has ten spines upon its masticatory edge; the lower lobe has the usual form, and has but one slender spine close to the hinder margin of the cutting edge.

In the *maxillipedes*, the stipes and lamina are completely separated by suture; the margins of both are smooth; the second joint of the palp is comparatively slender; its inner edge is beset with hairs along the distal half; close to the middle of the joint is an oval prominence as in the other deep-sea species.

One of the *second pair of ambulatory limbs* in the male is shown on Pl. III. fig. 5. The distal joint is as usual bent back upon the one in front like the blade of a closed penknife upon its handle; the penultimate joint is considerably broader at the base, and bears about fourteen somewhat slender spines, arranged in pairs.

The remaining ambulatory appendages (Pl. III. fig. 6) are slender, and but scantily furnished with slender spines, some of which are serrated; these are only to be found at the distal extremity of the third, fourth, and fifth joints, and extending for a short way along the outer margin of the fourth and fifth joints.

The *three anterior pairs of abdominal appendages* have a tuft of two or three hairs upon the projecting outer angle of the basal joint.

The suture upon the operculum is at right angles.

The *uropoda* are extremely small, and attached near the end of the lateral margins of the caudal shield.

Station 122c, September 10, 1873; lat. 9° 10′ S., long. 34° 49′ W.; 400 fathoms; bottom, red mud.

Station 146, December 29, 1873; lat. 46° 46′ S., long. 45° 31′ E.; 1375 fathoms; bottom, Globigerina ooze.

Station 147, December 30, 1873; lat. 46° 16′ S., long. 48° 27′ E.; 1600 fathoms; bottom, Diatom ooze.

The above cited Monograph of Grube contains a description and figures of a species of *Serolis* (*Serolis tuberculata*) which differs from all the species known at that time and from all those already described in the present Report by the characters of the fifth and sixth thoracic segments; the tergum of the fifth segment, which is generally narrower than the preceding ones, is in this species extremely narrow, not measuring more than one-sixth of the diameter of the segment in front, while the tergum of the sixth thoracic segment has entirely disappeared: the Challenger obtained two specimens of this same species, *Serolis tuberculata*, besides examples of four other species which agree with *Serolis tuberculata* in the characters just mentioned; all these species are inhabitants of the shallow waters off the southern and eastern coasts of Australia, and form a well-marked group, agreeing with each other in a number of structural points. These species I have briefly described in my "Preliminary Report," and named as follows:—*Serolis pallida*, *Serolis australiensis*, *Serolis elongata*, *Serolis minuta*, and *Serolis longicaudata*; all these species, with the exception of *Serolis minuta*, agree with each other and with *Serolis tuberculata* in the following points, some of which are peculiar to the group, while others again are not confined to the group, but are also to be found in other species.

They are all of small size; the females are larger than the males (?). The thoracic epimera are short and closely applied together for their whole length, while the epimera of the two abdominal segments are very short and not prolonged beyond the anterior margin of the caudal shield. The tergum of the fifth thoracic segment is extremely narrow; the tergum of the sixth segment is obsolete in the middle line, the suture which separates it from the succeeding first segment of the abdomen passes forwards and disappears underneath the segment in front (*cf.* Pl. VI. fig. 1) in *Serolis tuberculata* and *Serolis pallida*; in *Serolis australiensis*, *Serolis elongata*, and *Serolis longicaudata* the general appearance of the two last thoracic terga is the same, but a careful inspection shows that the posterior sutures of both segments become obsolete just before the middle line of the body, so that which apparently is the tergum of the first abdominal segment in reality includes also the middle part of the terga of the two last thoracic segments. In *Serolis minuta* the fifth and sixth thoracic segments are not quite so narrow as in the other Australian species. The fifth segment is divided off by a sutural line which is entirely continuous from one side of the body to the other; the sixth segment, however, though proportionately somewhat broader, resembles that of *Serolis australiensis*, &c., in being fused mesially with the succeeding abdominal segment. In the other Australian species the rostrum is long, reaching beyond the first joint of the anterior pair of

antennæ. The sterna of the abdominal segments are prolonged into stout spines in both sexes. The caudal shield is truncated at its extremity. The proximal joint of the anterior abdominal appendages is narrow, and, as in *Serolis schythei*, the basal triangular process furnished with branched hairs is absent; the suture on the operculum is at right angles to the long axis of the body. The palp of the maxillipede has this peculiarity, that the second joint, instead of being cordate in shape, has the two margins curved inwards and parallel with each other.

This assemblage of characters is very distinctive of all the Australian species with the sole exception of *Serolis minuta;* this latter appears to be intermediate between the other Australian species and the more typical species of *Serolis* such as *Serolis paradoxa;* in the characters of the last thoracic segments, as above stated, it more closely resembles the former, while in other respects it comes nearer to the latter; it would be difficult to classify it definitely with either; for this reason, and also considering the compactness in other respects of the genus, it appears to me inadvisable to divide *Serolis* into two separate genera or subgenera.

11. *Serolis tuberculata*, Grube (Pl. VI. figs. 1, 2).

Serolis tuberculata, Grube, Archiv f. Naturgesch., 1875, p. 227.

The Challenger obtained two specimens of a small species of *Serolis*, which I identify with Grube's *Serolis tuberculata;* one of these specimens is a male, the other a female; they were obtained from different localities, the male from Station 161, the female from Station 162; the former specimen is unfortunately much damaged.

The female is larger than the male—it measures 19 mm. long by 17 mm. broad; the length of the male is 12 mm., its breadth about the same. It appears therefore that the males of this species, if not smaller than the females, are broader in proportion to their length, as is generally the case in this genus. The colour of the two specimens is rather different; the female is pale yellowish brown, with innumerable black dots; on the outside of each epimeron is a larger black spot; the male is of a uniform but darker brown.

I have but little to add to Grube's excellent description of this species; in my specimens the epimera are not so closely applied together as he describes, and this is especially the case in the male, where the points of all the epimera project freely. On the cephalic shield between and in front of the eyes is a semicircular ridge of the integument; the convexity is directed forwards, and the two lateral ends are prolonged backwards into two short spines; the lateral tubercles on the thoracic segments are eight or nine in number on either side, and are situated on a low ridge which commences near the junction of the tergal portion of the segment with its epimeral portion, and terminate a little before the middle of the segment; this ridge is longer in the third free thoracic

segment than in the rest. The two last thoracic segments have only one tubercle on either side, which form the outer extremity of a slight ridge.

Antennæ.—The first pair of antennæ has a stem composed of four joints, of which the third is rather more than twice as long as either of the two basal joints; the filament consists of some fifty joints; in the second pair of antennæ (Pl. VI. fig. 2) the third joint has its posterior border prolonged into a spine as figured by Grube;[1] the upper surface of this and the succeeding joint has a strong longitudinally running ridge; the upper margin of the fourth and fifth joints, which are as usual the longest, is sinuous, and a tuft of hairs springs from the summit of each of the elevations; the filament has about twenty joints.

In the *maxillipedes* the stipes is almost triangular in shape; the lamina is proportionately very stout and strong, its diameter being equal to that of the stipes. Just below the articulation of the palp is a curved ridge; the second joint of the palp, instead of being heart-shaped, has its two sides almost parallel, the curvature of the outer margin following that of the convex inner margin.

The third pair of thoracic appendages is quite, as described by Grube, but I am inclined to think that both his specimen and mine are immature males (*ante*, p. 16).

The ambulatory limbs of this species are characterised by being mainly provided with one kind of spines which are of varying length, but always stout and strong. The end is bent and seems to be of a somewhat softer consistency than the rest. The stout serrated spines, so characteristic of the ambulatory limbs of other species of *Serolis*, are only present in small numbers in *Serolis tuberculata*.

The *three abdominal appendages* are hardly different from those of other species; the basal portion is, however, not prolonged into an angle bearing two or three plumose hairs as in many other species; in this respect they agree with *Serolis australiensis*, &c. The exopodite of the first pair of gills is divided into two by a transverse suture, which is at right angles to the long axis.

Generally speaking, the appendages of *Serolis tuberculata* are very closely similar to those of the next species to be described.

A figure of the female is given on Pl. VI. fig. 1.

Station 161, April 1, 1874; off East Moncœur Island, Bass Strait; depth, 38 fathoms; bottom, sand.

Station 162, April 2, 1874; off East Moncœur Island, Bass Strait; depth, 38 to 40 fathoms; bottom, sand.

[1] *Loc. cit.*, pl. v. fig. 2.

12. *Serolis australiensis*, F. E. B. (Pl. VI. figs. 3–8).

Serolis australiensis, F. E. Beddard, Proc. Zool. Soc. Lond., 1884, pt. iii. p. 334.

Of this species three examples were obtained by the Challenger off the coast of South Australia, and I have been able to compare them with a specimen in the British Museum brought from the same locality.

The largest specimen is a female (Pl. VI. fig. 4) and measures 14 mm. in length by 11 mm. in greatest breadth; the two remaining specimens are both males (Pl. VI. figs. 3, 7), and are approximately of the same size, measuring 10·5 mm. in length and 9 mm. in breadth.

Apart from the form of the third thoracic and second abdominal appendages, I could detect no marked differences between the two sexes, unless it be that the females are really larger than the males in this and in the other Australian species.

The general form of the body of *Serolis australiensis* is oval, the male a little broader proportionately; the distinguishing feature of this species is the immense number of tubercles which cover the body, and are especially large upon the caudal shield and the posterior margin of the segments.

The *cephalic shield* is broadest at the level of the eyes, where it bulges out considerably on either side. Anteriorly and posteriorly it is narrower; the anterior margin is prolonged into a very long rostrum; there is a transverse ridge which forms the anterior margin of the caudal shield for a short distance on either side of the rostrum, and then bifurcates, the outer branch continuing along the anterior margin of the cephalic shield and giving off a short spine directed forwards at the level of the end of the first joint of the anterior antennæ; the inner branch follows the margin of the cephalic shield, but at some little distance from it, and the two unite at the lateral anterior angle, enclosing between them a somewhat boat-shaped depression. The tubercles on the cephalic shield are arranged in transverse rows; there is a larger spine just to the inside of the posterior third of the eye on either side directed backwards and slightly outwards, and a median spine about the same size situated near the posterior margin of the cephalic shield.

Thorax.—The epimera of the first segment are not divided by a suture. The three following epimera are closely applied to each other along their whole length; there is a slight break between the four anterior and the two posterior epimera; the two latter are closely applied to each other, but the outer margin of the fifth begins to curve backwards a little before the outer termination of the fourth epimeron, so that the angle of the latter projects freely. All the thoracic epimera, with the exception of the first, are separated by a suture from the tergal portion of the segments.

The terga of the thoracic segments, as well as the epimera, are covered with minute tubercles, which are distributed in longitudinal rows running from one side of the segment to the other; one row, which is constant in all the segments, and is rather more conspi-

cuous than the rest, forms the posterior boundary of the segment, and is continued along the posterior margin of the epimera. In front of this is another row of tubercles, which in the middle of the segment lies half way between the anterior and posterior margins; on either side it divides into two rows, each of which run close to the anterior and posterior margins of the segment respectively; in the two last thoracic segments this anterior row of tubercles is not present. All the segments of the body, with the exception of the fifth and sixth, the former of which, as in the other Australian species, disappears altogether in the middle line, are furnished with a larger tubercle exactly in the median dorsal line; these increase in size from before backwards; on the fifth segment (in the female specimen at least) the median tubercle is wide, and flattened and quadrifid at its extremity.

Abdomen.—The epimera of the second and third abdominal segments extend for a very short space beyond the lateral margins of the caudal shield; beneath, the three anterior segments are prolonged into a stout spine of unusual length (*cf.* fig. 3); the spine of the first segment, which is the longest, completely covers the spine of the succeeding segment; the spines in the female appear to be a little stouter than in the male, for in the male the spines are all rather slender; the differences, however, are insignificant and not well marked.

The *caudal shield* is more or less triangular in outline, distinctly carinate and truncated at its free extremity; its upper surface is covered with tubercles, which have no definite arrangement except for a median transverse row which crosses the central keel at right angles a little below the attachment of the uropoda; one of these tubercles on either side, close to the lateral margin, is considerably larger than the rest.

Of the *first pair of antennæ* the two proximal joints are short, while the third, which is the longest, measures about twice the length of the second. The joints of the filament are extremely short and numerous; there are about fifty; each joint bears two sensory filaments instead of the usual one (Pl. VI. fig. 5).

In the *second pair of antennæ* the third joint has a large backwardly projecting tubercle just before its articulation with the following joint as in *Serolis tuberculata;* this joint is also smaller than the preceding one; the fourth and fifth joints are as usual greatly elongated, and the outer margin is sinuous. A tuft of fine hairs springs from the surface of each of the four elevations; the filament consists of fifteen joints, which are longer and more slender than the joints composing the filament of the first pair of antennæ; the upper surface of the third to the tenth joints has a row of short blunt tubercles; one or two long fine hairs springs from the inner margin of each joint at its anterior extremity.

Mouth Appendages.—The *mandibles,* like those of *Serolis pallida,* have a large and conspicuous tooth upon the posterior part of the masticatory edge; behind this is another smaller tooth; in front the margin slopes back gradually to meet the outer margin of the mandible.

The first *maxillæ* are short and rather bent, and resemble those of *Serolis pallida*.

Thoracic Appendages.—The *maxillipedes* (Pl. VI. fig. 6) closely resemble those of *Serolis pallida* and the other Australian species, but are not sculptured like those of the former; the lamina terminates on the inner side in the usual way; on the outer side it is produced into a rounded prominence, which extends some way beyond the notch on the inner side; just behind the articulation of the palp is a broad ridge as in *Serolis pallida*; the anterior margin of the stipes is crenate; the second joint of the palp is not so distinctly cordate in shape as in many species, and resembles in this particular the other allied Australian forms.

The thoracic appendages are furnished with two kinds of spines—(1) short broad serrated spines like those of *Serolis schythei* and many other species, (2) longer and more delicate spines, which are somewhat thicker on the outer edge than on the inner; the extremities are bent inwards; these spines seem only to be found on the appendages of the Australian species. The proximal joint of all the ambulatory limbs has a number of fine branched hairs on the inner surface like those of *Serolis neæra* and other species; the second joint is a little shorter, and has one long hair on the inner side just before its articulation with the succeeding joint; the third, fourth, and fifth joints are short, but increase in length up to the fifth. One of the thoracic appendages is shown in fig. 8; the others are similar except that the three penultimate joints increase in length in the posterior limbs; in the appendage figured it will be seen that the spines on the outer side arise from step-like processes, on the three penultimate joints the number of these steps gradually increases in the posterior appendages. In the male the second thoracic appendage, as in all other species, is modified into a prehensile organ; the penultimate joint is rather more elongated than usual, and its two sides are almost parallel; on the inner surface I counted in one specimen nine of the hairs peculiar to this joint.

The first three pairs of *abdominal appendages* have no hairs upon the basal joint, and the two sides of this joint are nearly parallel owing to the absence of the inner projecting angle.

Station 162, April 2, 1874; lat. 39° 10′ 30″ S., long. 146° 37′ E.; 38 fathoms; bottom, sand and shells.

13. *Serolis elongata*, F. E. B.

Serolis elongata, F. E. Beddard, Proc. Zool. Soc. Lond., 1884, pt. iii. p. 335.

Although I have been able to examine only a single female example of this species, its characters appear to me to be sufficiently different to retain it as a distinct species.

The specimen is a female with fully developed ovigerous lamellæ; its greatest length is 10 mm., its greatest breadth 6·5 mm. It is most nearly allied to *Serolis australiensis*, from which, however, it differs in several respects.

From the above measurements, when compared with those of *Serolis australiensis* (*ante*, p. 68), it will appear that *Serolis elongata* is rather narrower, the length being proportionately greater than the breadth.

The main difference, however, between the two species is the development of tubercles upon the dorsal surface of the body; *Serolis australiensis* is to be distinguished from all other species of the genus by the immense number of tubercles upon the segments of the body, and also upon the caudal shield; in *Serolis elongata* the dorsal surface of the body is by comparison almost smooth; this cannot be owing to the difference of age; the female specimen of *Serolis elongata*, although actually smaller than *Serolis australiensis*, is perfectly mature, with fully-developed ovigerous lamellæ; and as no other species that I have been able to examine undergoes any change, except mere increase in size, as soon as it has attained to maturity, there is no reason to suppose that *Serolis elongata* is peculiar in that respect. As in *Serolis australiensis*, each of the segments of the body is furnished with a curved hook-like spine in the middle line; a row of short tubercles occupies the hinder portion of each of the segments, and is prolonged on to the epimera; besides these there appear to be a few scattered tubercles over the rest of the segments and the epimera, which are very inconspicuous, and contrast with the strongly tuberculated surface of the body in *Serolis australiensis*.

The caudal shield has the same general shape that it has in the last mentioned species, with serrated margins and a longitudinal carina. There is also a lateral carina on either side bearing a short spine, which is situated about half way down the caudal shield, and a little below the place where the uropoda are attached, and terminating at the end of the body by becoming fused with the central carina; as in *Serolis australiensis*, these lateral carinæ are serrated. Between these and the central carina is a short ridge running obliquely towards the margin of the caudal shield from a point a little below and to one side of the commencement of the central carina; the general surface of the caudal shield is smooth, and there are only present a few scattered tubercles, especially developed in the neighbourhood of the two lateral carinæ.

Port Jackson, Sydney, 30 fathoms.

14. *Serolis longicaudata*, F. E. B. (Pl. VII. figs. 8–10; Pl. VIII. figs. 1, 2).

Serolis longicaudata, F. E. Beddard, Proc. Zool. Soc. Lond., 1884, pt. iii. p. 336.

Of this species the Challenger obtained one immature female; its length is 7 mm., its breadth 5 mm.

The general form of the body is peculiar, and unlike that of the typical members of the genus; the anterior portion of the body, comprising the head, thorax, and free abdominal segments is almost completely circular, and the caudal shield projects backwards for a considerable distance, being proportionately longer than in any other of the species

known to me, while the epimera are all short and abruptly truncated, reaching in no case beyond the lateral margins of the caudal shield.

The *cephalic shield* terminates in front in a comparatively long rostrum; behind, the suture which separates it from the thoracic segment is incomplete in the middle line, and for a space on either side of it extending to nearly as far as the level of the eyes; the cephalic shield as well as the rest of the body is quite smooth, and free from tubercles.

Thorax.—The epimera of the first thoracic segment are entire and devoid of any trace of a transverse suture; the epimera of the remaining thoracic appendages are very short, and have the appearance of being truncated at their free extremity; the anterior margin of the epimeron, instead of passing insensibly into the outer lateral margins, meets it almost at right angles, and the outer margins run backwards in a direction almost parallel to the long axis of the body; the epimera of the three anterior free thoracic segments are separated by a distinct suture from their terga. The epimera are extremely short, as may be seen in Pl. VIII. figs. 1, 2, where this species is figured. The two last thoracic segments have the same characters that are peculiar to the other Australian species of the genus; the tergum of the fifth is extremely narrow, not more than one-fourth the breadth of the segment in front; the tergum of the sixth segment is entirely absent. The sutures which separate both segments from the succeeding and preceding ones entirely disappear close to the middle line of the body.

The outer margins of all the thoracic epimera are faintly serrated. Ventrally the middle portion of the segments is elevated into a broad ridge which becomes higher towards the middle line, and slopes off gradually in the direction of the epimera; in the sixth segment this ridge is still more marked, and being developed upon its posterior border overlaps the terminal thoracic segment. The terminal segment of the thorax bears on either side, close to and just above the attachment of the first abdominal limb, a circular aperture which may be the outlet of some gland. I observed a similar pair of orifices in *Serolis pallida* and in several other species.

Abdomen.—The epimera of the second and third abdominal segments extend as far as the edge of the caudal shield; the outer margin of the second is concave, that of the third nearly straight. The ventral portion of the first three segments is furnished with a central triangular keel which projects some way back as a stout conical spine; the spine is largest upon the first segment, and its cavity communicates with the exterior by several large fenestræ upon the lower surface (Pl. VII. fig. 8).

The *caudal shield* has a somewhat pentagonal outline, and terminates in an abruptly truncated extremity; the dorsal surface has a middle and two lateral carinæ; the portion which lies beyond the latter is strongly bent down; the postero-lateral margins are slightly denticulate.

Appendages.—The *antennæ* are displayed in figs. 9 and 10 of Pl. VII. The anterior pair (fig. 9) are rather shorter than the second pair; their terminal filament has thirteen

joints. In the posterior antennæ (fig. 10) the filament has ten joints; the two last joints of the basal portion of the antenna are furnished with tufts of fine hairs springing from shallow depressions on the anterior surface.

The *ambulatory limbs* are remarkable in that they are only furnished with comparatively slender, soft, bluntly terminating spines; no serrated spines appear to be present. The inner side of the first joint of all these appendages has a row of about a dozen fine branched hairs entirely like those found in many other species; the second joint in all is rather smaller than the first, and has on the inner side just before its termination a single long slender spine; the remaining joints are subequal in size and comparatively short; the fourth and fifth joints in the penultimate pair of appendages are longer and narrower than in the preceding limb, and about half as long again as the third joint.

The last pair of thoracic appendages is as usual small.

The *three first abdominal appendages* have the basal portion comparatively long and narrow, and as in other Australian species the inner and lower margins are not prolonged into a triangular process furnished with two or three branched hairs.

The *fourth pair* or *operculà* have the exopodite divided by a suture at right angles to the longitudinal axis, and terminating exactly at the level of the attachment of the uropoda; the latter are attached at about the middle of the caudal shield, and extend exactly as far as its termination; the endopodite is slightly shorter, and at the same time slightly broader than the exopodite; the margins of both are smooth, and only slightly crenate at the distal end; they bear no branched hairs.

Station 161, April 1, 1874; lat. 38° 22′ 30″ S., long. 144° 36′ 30″ W.; 33 fathoms; bottom, sand.

15. *Serolis pallida*, F. E. B.(Pls. VII. fig. 1; VIII. figs. 6–16).

Serolis pallida, F. E. Beddard, Proc. Zool. Soc. Lond., 1884, pt. iii. p. 335.

Of this species two specimens were obtained, a male and a female. The female is the larger, measuring 16 mm. in length and 13 mm. in breadth; the male measures 9 mm. in length and 7 mm. in breadth.

The body is oval, somewhat pear-shaped, and recalls *Serolis convexa;* as in that species the epimera are closely applied to each other, and only in the last three thoracic epimera are the extremities freely projecting. The colour (in alcohol) is a uniform pale brown, with two darker patches on each side of the third free thoracic segment, the anterior portion of the caudal shield is whitish grey. The surface of the body is quite smooth and free from tubercles except for a series, one to each segment, occupying the median line.

The *cephalic shield* is almost triangular in shape, from the great development of the ocular prominences and a large median backwardly projecting spine; the rostrum is long and slender, and reaches nearly as far as the distal end of the second joint of the posterior antennæ; the anterior margin of the cephalic shield is thickened into a ridge, which bifurcates at the edge, the two branches being directed forwards and enclosing a deep cup-like space; shortly before the bifurcation a small spine-like process is given off anteriorly.

Thorax.—The epimera are short, gradually increasing in length up to the sixth pair; the first epimera are entire as in the other Australian species, and not divided by any transverse suture; at the upper extremity is a short ridge on either side, which extends for about one-sixth of its length parallel to the anterior margin of the epimeron.

In the three succeeding epimera the curvature of the outer margin is very slight, which gives them the appearance of being abruptly truncated. The fifth epimera are more sickle-shaped, since the outer is inclined at a smaller angle to the posterior margin; the outer margin of the sixth epimera is concave.

The terga of the thoracic segments, with the exception of the first and the two last, have a median hooked spine directed upwards and backwards; these increase slightly in size from before backwards; the antero-posterior diameter of three anterior free thoracic segments is about the same; the fourth is not more than one-fifth as wide as the preceding segments, and the tergal portion of the last thoracic, as in other Australian species, has entirely disappeared.

Abdomen.—The epimera of the second and third abdominal segments only reach as far as the margin of the caudal shield; they are equal in length. The terga of the three segments are furnished with a spine like that in the thoracic segments; these spines, which are rather smaller than those on the thorax, increase in size from before backwards. The sterna of these segments are produced into a long median spine, which is larger in the first segment than in the two succeeding ones.

The *caudal shield* in the female measures 5·5 mm. in length, and is therefore rather more than one-third of the length of the entire animal; it is irregularly hexagonal in outline, and keeled; the extremity is notched; the uropoda are attached about half way down; just below and to the inside of the spine-like process which covers the articulation of the uropoda is a minute flattened spine on either side.

The two pairs of *antennæ* are approximately of the same length. The basal joint of the first pair (Pl. VIII. figs. 7, 8) has three strong tubercles on its upper surface; the second joint has a stout tubercle on the posterior margin projecting backwards; the filament has twenty-four joints, each of which is furnished with two sensory hairs (fig. 8), as in *Serolis australiensis*.

In the second pair of antennæ (Pl. VIII. fig. 6) the fifth joint is very much enlarged; it is not quite so long as the preceding joint, but wider; the filament is short, being

composed of nine joints. The second and third joints of the antennæ are raised into tubercles on the upper surface.

Mouth Appendages.—The *mandibles* (Pl. VIII. figs. 9, 10) as well as the maxillipedes (fig. 12) are much sculptured, the under surface being raised into a number of ridges separated by deep depressions as shown in the figure; the masticatory edge, instead of being comparatively straight and smooth, as in the majority of species, is denticulate, one tooth on its posterior boundary being specially prominent. On the upper surface (fig. 10) are two spine-like processes.

The *maxillæ* do not differ much from those of other species; the anterior pair (fig. 11) have a short basal joint, and the terminal joint is much bent.

The *maxillipedes* are shown on fig. 12 of Pl. VIII.; the under surface of the basal portion, instead of being flat and smooth, as is ordinarily the case in *Serolis*, is traversed by a number of ridges, the direction and form of which are displayed in the figure; the second joint of the palp has the peculiar shape that it has in *Serolis australiensis*. The outer margins, instead of being convex, are concave and almost parallel with the inner margins; they are traversed from end to end by a ridge, close to and quite parallel with the outer margins.

The *second pair of thoracic appendages* are shown on fig. 13 of Pl. VIII., and several of the spines from the inner surface of the penultimate joint on figs. 14, 15 of the same plate. The latter are very characteristic in shape—the longer spines terminate in two large oval expansions traversed by longitudinal striæ which converge at the proximal extremity; the anterior of the two is shorter and broader than the posterior; but at the hinder end of the joint they become much smaller and nearly equal in size and similar in shape; between the two wing-like processes the axis of the spine is continued into a thicker cylindrical tapering extremity which reaches a trifle beyond the level of the posterior wing-like process.

The *third pair* are in the male modified in the ordinary way (Pl. VIII. fig. 16). The penultimate joint is oval, and furnished on the inner surface with six or seven pairs of cylindrical spines, the axis of which is prolonged into a short filiform process. The first joint, as in the succeeding ambulatory limb, has a row of fine branched hairs on the inner side.

The *remaining thoracic appendages* are stout and strong, and furnished with serrated spines, especially upon the outer surface; the second joint has invariably a single slender spine springing from about the middle of the inner surface; the third, fourth, and fifth joints increase progressively in size, the fifth joint being nearly or quite as long as the second, though narrower.

The *three first abdominal appendages* have no inner angle bearing hairs upon the basal joint.

The suture which traverses the exopodite of the operculum is at right angles

to the longitudinal axis, and at the level of the end of the first joint of the uropoda.

The *uropoda* are attached just before the end of the anterior half of the caudal shield; the exopodites are longer and reach very nearly up to the distal extremity of the caudal shield; they are oval in shape, and terminate in a blunt extremity; the outer margin is serrated nearly as far as the articulation; the endopodite is relatively broader, and ends in a truncated notched extremity, the outer and the posterior margins are serrated; no hairs were found upon these appendages, but it is very probable that they may have become detached.

Station 162, April 2, 1874; lat. 39° 10′ 30″ S., long. 146° 37′ E.; 38 fathoms; bottom, sand and shells.

Station 163, June 3, 1874; off Port Jackson; 30 to 35 fathoms.

16. *Serolis minuta*, F. E. B. (Pl. VII. figs. 2–6).

Serolis minuta, F. E. Beddard, Proc. Zool. Soc. Lond., 1884, pt. iii. p. 337.

The Challenger collection contains only one specimen of this species, which is a male, and measures 5 mm. in length and 5 mm. in diameter; this species, therefore, if full grown, is the smallest known.

In general shape *Serolis minuta* resembles very closely *Serolis cornuta*; the outline of the body is almost circular, and the caudal shield projects only a little way beyond the circle. A conspicuous keel runs down the middle of the body.

The *cephalic shield* terminates in front in a short and stout rostrum; the anterior portion, as in most other species, is traversed by a ridge (*cf.* Pl. VII. fig. 2) arising from the base of the rostrum; the ridge is continued on to the epimera; the posterior margin is provided with three blunt tubercles, of which the middle one is the largest; each of the following segments is similarly produced into a blunt tubercle at the median point of the posterior margin.

Thorax.—The *first thoracic segment* is entire, and not separated into two portions by a transverse line of division as is the case in so many other species. The dorsal surface of the remaining segments is prolonged on either side into a triangular process which slightly overlaps the succeeding segment; these processes, which are hollow, serve for the attachment of the muscles moving the limbs; they are situated on the tergal portion of the segment close to its junction with the epimeral portion; while those of the third, fourth, and sixth segments are the largest and most conspicuous.

The tergal portion of the second, third, and fourth segments is separated by a distinct suture from the epimera. The sixth segment is partially fused with the first abdominal segment, the suture which divides them being incomplete for a short space on either side of the median line; its epimera extend about as far as the first third of the caudal

shield; the outer margins of the epimera in all the segments are smooth, without serrations or hairs. On either side of the male generative pores is a slit-like orifice as in *Serolis pallida*, &c.

Abdomen.—The second and third segments are provided with epimera which extend farther than the epimera of the sixth thoracic; those of the third segment reach nearly as far as the middle of the caudal shield. The ventral portion of the three anterior abdominal segments is shown on Pl. VII. fig. 2′, together with the appendages belonging to them; they are oblong in shape, and each overlaps the succeeding one; the posterior margin of the first is almost straight, in the others slightly convex.

The *caudal shield* is almost triangular in shape, and ends in a blunt prolongation; the upper surface slopes gently downward on either side from the central keel; the lateral margins commencing from the attachment of the terminal appendages curve inwards and then slightly outwards, becoming almost parallel just before their termination.

Antennæ.—One of the antennæ of the first pair is figured on Pl. VII. fig. 4; it consists as usual of four joints and a terminal filament; the proximal joint is round and entirely free from hairs; the second joint is the largest, its lower surface is furnished with a row of short hairs which are continued on to the succeeding joint; the third joint is smaller than the second, and the fourth is still smaller. The filament is made up of ten joints, of which the first eight are subequal; the penultimate joint is very small, and the last slender and elongated. The second pair of antennæ (Pl. VII. fig. 5) are about one-third longer than the anterior pair; the basal portion consists of five joints, of which the last is the longest; the three last joints are furnished with bundles of hairs arranged irregularly over the lower surface. The filament is made up of ten joints, and is almost exactly of the same length as the filament of the anterior antennæ, which is an unusual circumstance.

The *mandibles* present the usual form, and terminate in a blunt masticatory edge.

Thoracic Appendages.—The large prehensile organs which form the second pair of thoracic appendages are in general form entirely similar to those of other species, but the spines developed upon the inner margin are as usual distinctive; several of these are shown in Pl. VII. fig. 7.

The *third pair* are modified into a prehensile organ which presents some peculiarities distinguishing it from the same appendage in other species of *Serolis*. Fig. 3 represents the last three joints of the right hand appendage viewed in profile and from beneath.

The terminal joint is furnished with a remarkable tongue-shaped process arising from the inner side close to the distal end; along this runs a median crest like the midrib of a leaf. The penultimate joint has five pairs of conical bent spines which are almost exactly similar in shape to those of *Serolis convexa*. The fourth joint has a bundle of fine closely-set long hairs on its inner surface, as is the case in *Serolis neœra*; the third joint has several smaller bundles of precisely similar hairs separated by intervals from each

other; this recalls the same appendage in *Serolis neœra*, where, however, the third joint is completely covered on its inner side with a dense bundle of hairs.

The succeeding thoracic appendages differ from the same appendages in all other species of *Serolis*, by the fact that they are provided only with long slender hairs; the serrated spines so generally found on the ambulatory limbs are entirely absent. The first ambulatory limb of the left side (fourth thoracic appendage) is displayed on Pl. VII. fig. 6. As in other species, the proximal joint is the largest and has no hairs; the second joint has a few hairs on the inner surface; the three following joints are furnished with hairs arranged in bundles as shown in the figure, and more abundantly developed upon the outer than upon the inner edge.

The remaining ambulatory limbs increase slightly in size with the exception of the last, which, as in other species, is the smallest of the series. In the structure and the arrangement of the hairs upon the several joints, they present only a few very slight differences from the one figured; for example, the second joint bears a single long hair upon its outer surface, except in the last pair, where there are three, separated from each other by equal intervals.

The first three *abdominal appendages* present no special characters worthy of remark, except that the basal joints are entirely unprovided with hairs, and resemble therefore *Serolis schythei*.

The terminal pair of abdominal appendages—the uropoda—are attached close to the upper end of the caudal shield; both the distal joints are narrow and elongated, and slightly serrated upon the outer margin; the inner joint is the shorter of the two, and its posterior margin is markedly dentate, and bears a number of hairs.

The colour of this species (in spirit) is brown, owing to the very slight development of pigment, which is chiefly concentrated along the lateral portions of the terga and the marginal portion of the caudal shield.

The specimen was dredged at Station 161, off the entrance to Port Philip, Australia, on April 1, 1874, in 38 fathoms.

GEOGRAPHICAL AND BATHYMETRICAL DISTRIBUTION.

The geographical range of the genus *Serolis* is almost entirely restricted to the southern hemisphere; so far as is known at present, this is the case with the abyssal as well as the shallow-water species; there is only one exception in *Serolis carinata*, a species which has been described by Lockington,[1] and said to occur so far north as at San Diego in California.

The shallow-water species of *Serolis*, with the exception of *Serolis carinata* and a more doubtful exception, *Serolis paradoxa*,[2] are confined to the Antarctic area.

Within this area there appear to be four centres of distribution, corresponding in fact to all the land masses that lie within it—(1) the shores of South America as far north as lat. 30°, the Falkland Islands and the South Shetlands; (2) Kerguelen, the Crozets, and Marion Island; (3) New Zealand (?); (4) the shores of Southern and Eastern Australia.

A Kerguelen species, *Serolis latifrons*, is also known to occur at the Auckland Islands, off the south of New Zealand, a single specimen having been obtained at Rendezvous Cove in that island during the voyage of the "Erebus" and "Terror." It seems very probable also that the genus will eventually be found to inhabit the shores of New Zealand, though at present there is no certain evidence to that effect. Miers, in his list of New Zealand Crustacea, includes *Serolis paradoxa*, apparently on the authority of a specimen in the British Museum, and the same collection of Crustacea contains a single example of a species which I have identified with the Patagonian *Serolis schythei*, and which is labelled "New Zealand"; in both these cases, however, I believe that the locality is not authenticated beyond a doubt. Considering the general similarity between the Crustacean fauna of the whole "Antarctic region" from Patagonia to New Zealand, it seems very probable that *Serolis* is an inhabitant of the shores of New Zealand. I have called attention later (p. 82) to the fact that *Serolis bromleyana* occurs off the shores of New Zealand in *deep* water.

From the shores of South America seven species have been described; these are *Serolis paradoxa*, *Serolis trilobitoides*, *Serolis gaudichaudii*, *Serolis plana*, *Serolis schythei*, *Serolis convexa*, and *Serolis serrei*; of these species *Serolis gaudichaudii* extends farther north than any of the rest; the original specimen was obtained by M. Gaudichaud[3] near Valparaiso. Cunningham[4] also mentions that he obtained it at the same locality. *Serolis schythei* was dredged during the voyage of the Challenger as far north as the Gulf of Peñas on the west coast; it also occurs in the Strait of Magellan and at the

[1] *Loc. cit.*

[2] This species is stated by Dr. Leach, on the authority of Dufrésné, to inhabit the shores of Western Africa, about the river Senegal, but it has never subsequently been obtained from that locality.

[3] Audouin and Milne-Edwards, *Arch. d. Mus. d'Hist. Nat.*, *loc. cit.*, p. 25.

[4] *Loc. cit.*

Falkland Islands. *Serolis trilobitoides* is said by Eights to inhabit the coasts of the South Shetland Islands, as well as the neighbourhood of Cape Horn; the remaining species seem to be restricted to the Strait of Magellan and the extreme south of Patagonia.

It is possible that *Serolis trilobitoides* will eventually prove to be the same species as *Serolis cornuta* from Kerguelen; the two are at least very closely allied.

With this exception the species that inhabit Kerguelen are in every case quite different from the South American species. Besides *Serolis cornuta*, two others inhabit the shores of Kerguelen, viz., *Serolis latifrons* and *Serolis septemcarinata*; the first of these occurs also in comparatively deep water (210 fathoms) off the Crozets. *Serolis septemcarinata* is common to all three groups of Antarctic Islands, Prince Edward and Marion Islands, the Crozets, and Kerguelen,—while *Serolis cornuta* was dredged off the Crozets during the cruise of the "Gazelle."

Finally the shores of the southern and eastern parts of Australia are inhabited by six species of *Serolis*, viz., *Serolis tuberculata*, *Serolis australiensis*, *Serolis longicaudata*, *Serolis elongata*, *Serolis minuta*, and *Serolis pallida*; these species, with the exception of *Serolis minuta*, form, as has already been pointed out (*ante*, pp. 65, 66), a well marked subdivision of the genus, differing more from either the Kerguelen or the South American species than any of these do from each other.

It is rather premature to draw any general conclusions from these facts, even with regard to the distribution of the genus *Serolis* alone; but it may at any rate be pointed out that the distribution of this genus, as at present known, seems to necessitate the division of the southern hemisphere into two distributional provinces, (1) an Antarctic, reaching from South America to New Zealand, and (2) an Australian.

The genus *Serolis* seems to attain to its greatest development in point of number of individuals on the shores of Patagonia and at Kerguelen; v. Willemoes Suhm states[1] that at Kerguelen *Serolis* forms no less than 20 per cent. of the Crustacean fauna; and that "a large species (*Serolis cornuta*) is the predominant and most characteristic form of all the Crustacea in the shallow water of the Antarctic Islands."

It is true that nearly as many species are now known from Australia as from Patagonia, but the genus does not appear to form an important element in the fauna of the first mentioned locality; only a very few specimens, not more than two or three, of any of the six species were obtained by the Challenger; the fact that no species have been previously described[2] either by resident naturalists or from collections made by exploring vessels, also indicates the rarity of the genus in this region. In Patagonia, on the other hand, there are not only a comparatively large number of species, but the number of individuals is also great, though apparently not forming so important an element in the fauna as at Kerguelen.

[1] *Proc. Roy. Soc.*, vol. xxiv. p. 590.

[2] With the sole exception of one specimen of *Serolis tuberculata* described by Grube, as quoted above.

The deep-sea species of *Serolis* have a wider range to the north than the shallow-water species, though as yet none have been obtained north of the equator; since there are only four deep-sea species known, and, with the exception of *Serolis bromleyana*, only a small number of specimens of each were dredged, it is perhaps rather premature to draw any deductions from the facts, and the following notes must be accepted for what they are worth.

In the first place, it must be noted that in no case do any of the shallow-water species pass the 300 fathom limit; nor are any of the deep-sea species known to inhabit shallow water; the shallow-water are specifically distinct from the deep-sea forms. I may correct here a misleading statement in Gerstaecker's account of the Isopoda in Bronn's Thierreichs, from which it would appear that one species is common to "deep" and "shallow" water; on p. 241 of the above quoted work, Gerstaecker gives a list of the range in depth of the family Serolidæ, and one species, which is my *Serolis antarctica*, is stated to occur in 100 fathoms off the Brazilian coast, and again in 1375 and 1600 fathoms in the neighbourhood of the Crozets; 100 is a misprint for 400, which is the actual depth at which the species was dredged.

Two out of the four deep-sea species have a comparatively wide horizontal as well as vertical distribution; one of these, *Serolis antarctica*, occurred at Station 120 (675 fathoms), off Pernambuco, and again at Stations 146 and 147 (1375 and 1600 fathoms), between Prince Edward Islands and the Crozets; the other, *Serolis bromleyana*, was obtained at four localities between Australia and New Zealand, Station 164B (410 fathoms), at Stations 168 and 169, off the east coast of New Zealand, in 1100 and 700 fathoms, and again, considerably to the south, close to the Antarctic Ice-Barrier, at Station 156 (1975 fathoms); Gerstaecker, in the work already alluded to, calls attention to an obvious corollary from these facts (which have been already mentioned in v. Willemoes Suhm's Preliminary Report on the Crustacea observed during the voyage of the Challenger[1]), namely, that these two species, as well as others which have a wide distribution, are found in deeper water passing southwards from the equator to the pole; the facts in the distribution of *Serolis bromleyana* appear to me to furnish grounds for another deduction, that the size of the individuals increases as they pass southwards and into deeper water; the specimens dredged at Stations 164B and 169 (410 and 700 fathoms respectively) are all small; out of the nine or ten specimens dredged at Station 168, farther south and deeper water (1100 fathoms), five are of considerable size, almost twice as large as those obtained at the two first-mentioned stations; finally, at Station 156, the southernmost point at which the species was dredged, two specimens half again as large as the largest of those from Station 168 were dredged up from 1975 fathoms.

Serolis antarctica also agrees in these respects with *Serolis bromleyana*, though the facts in this case are not so strong, inasmuch as only a single specimen was dredged at

[1] *Proc. Roy. Soc. Lond.*, vol. xxiv. p. 585, 1876.

the northernmost station in comparatively shallow water (Station 120, 675 fathoms); this specimen is, however, distinctly smaller than any of those obtained in deeper water at Stations 146 and 147.

It must be remembered, of course, that Gerstaecker's statements as well as mine depend after all upon very few facts; it would be extremely rash at present to insist upon any such generalisation as has been put forward by Gerstaecker in the work already quoted, but it seems worth while to call the attention of naturalists to the facts such as they are.

The remaining deep-sea species were dredged close to the east coast of South America; *Serolis gracilis* from a single Station (Station 120), off Pernambuco, in 675 fathoms, and *Serolis neœra* from two Stations close together and a little farther to the south, off Buenos Ayres, at Stations 320 and 318, in 600 and 2040 fathoms respectively; 2040 fathoms is the greatest depth which the genus is known to inhabit.

It appears therefore that the deep-sea forms of the genus, although not absolutely confined to the neighbourhood of the great continents, attain to their greatest development both in number of species and individuals in this situation, and are never found at any distance from some land—continent or oceanic island.

The genus *Serolis* has evidently originated in the southern hemisphere, probably round the shores of the south polar continent, and has thence spread northwards, its range being apparently limited by temperature; accordingly we find that in every case those species which occur near the equator (*Serolis gracilis, Serolis antarctica, Serolis neœra*) occur there in deep water where the conditions, as far as temperature is concerned, are not so different from the conditions which must obtain on the shores of Kerguelen and Patagonia; the one fact, however, which seems to militate against such an hypothesis is the occurrence of *Serolis carinata* in *shallow* water as far north as San Diego in California. It must be remembered, however, that the temperature of that portion of the Pacific is not so high as might be expected from its latitude; a cold current from the Antarctic area sweeps along the western shores of South America, and the existence of this current has perhaps rendered it possible for *Serolis carinata* (or its ancestors) to migrate farther to the north than would be possible, for example, on the eastern shores of the same continent; moreover, a glance at the map of the world will show that here alone is there any direct land communication between the area occupied by the shallow-water species of the genus *Serolis* in the southern hemisphere and the more northern regions; elsewhere tracts of deep water have possibly aided in preventing their access to the equatorial regions and the northern hemisphere, though it seems more probable, from what has already been said, that the distribution of the group has been more restrained by conditions of temperature than by any other cause.

Comparing the deep-sea with the shallow-water species of *Serolis*, it appears (1) that the genus is pre-eminently a shallow-water genus, the number of deep-sea forms being

comparatively small; (2) that, as has already been pointed out, the deep-sea are in all cases distinct from the shallow-water species; (3) that the deep-sea species show certain peculiarities, notably in the structure of the eyes, which, as has already been described (p. 20 *et seq.*), are either entirely absent (*Serolis antarctica*) or, if present, show great evidence of functional degeneration; none of the deep-sea species possess well-developed eyes. To compensate for the want of eyes, there is a great development of sensory hairs on certain of the appendages; the males of *Serolis neœra*, *Serolis bromleyana*, and *Serolis gracilis* have, upon the third, fourth, and fifth joints of the third thoracic appendages, tufts of sensory hairs, which have already been described (pp. 55, 59, 62; Pl. IV. fig. 6; Pl. V. fig. 8). This structural feature is not, however, peculiar to the deep-sea species, inasmuch as it is also found in *Serolis paradoxa;* but since it occurs in three out of the four, and *Serolis paradoxa* is the only shallow-water species in which I have noticed it, it may be considered as characteristic. *Serolis antarctica* does not agree with the other deep-sea species in this respect, but the first pair of antennæ are furnished with a larger number of sensory filaments than is usual—two upon each joint of the filament; several shallow-water species, however, *Serolis pallida*, *e.g.*, and *Serolis convexa*, present the same character.

In two of the deep-sea species, *Serolis bromleyana* and *Serolis neœra*, the genus attains to its greatest size, and these are indeed among the largest of the Isopoda; as a general rule the deep-sea representatives of the Isopoda are not distinguishable from their shallow-water allies by their greater size; there are exceptions to this rule, notably in the case of *Bathynomus*, a deep-sea genus recently described by Milne-Edwards, which is no less than 9 inches long; and the Challenger collection contains a specimen of another Isopod belonging to the same family Cymothoadæ, which is also of considerable size. The elongated and spine-like epimera of *Serolis neœra* and *Serolis bromleyana*, and also, though to a less extent, of *Serolis gracilis*, are unlike anything that is met with in the representatives of the genus from shallow water, where the epimera are always moderately developed in comparison. In all the deep-sea species, without exception, the ambulatory limbs are furnished with comparatively few spines, which are generally soft and delicate. The strong sword-like and serrated spines so commonly found in the shallow-water members of the group are either completely or partially absent; a very general character, inasmuch as it is found in two out of the four deep-sea species (*Serolis neœra* and *Serolis gracilis*), is the presence, upon the ambulatory limbs, of plumose hairs similar to those which are found upon the abdominal appendages; in *Serolis neœra* especially are these plumose hairs developed in great abundance. They have been more particularly described above, on pp. 55, 56.

The maxillipedes in all the deep-sea species possess a short tubercle on the inner side of the middle joint of the palp, which may represent some kind of sense organ, though the hairs with which it is thickly covered are in no way different from the hairs

which cover the rest of the palp. This is represented in Pl. III. fig. 10, *a*, which is drawn from the maxillipede of the right side of *Serolis gracilis;* with this figure may be compared Pl. I. fig. 11, which represents the same appendage in *Serolis cornuta;* this character is so trifling, that if it were not regularly present in all the deep-sea species, and as regularly absent from all the shallow-water species, with which I am acquainted, it would indeed be hardly worth mentioning. In a young specimen of *Serolis antarctica* from the brood cavity of the mother, in which the appendages are still in a comparatively undeveloped condition without any hairs and spines, this prominence is conspicuous upon the palp of the maxillipede, and is armed upon its upper surface with a short pointed spine; it is possibly the rudiment of some structure highly developed in the ancestors of the group.

NOTE.

In the Plates which accompany this Report the figures of the animals themselves were in most cases drawn by Mr. Mintern from the actual specimens; the appendages were lithographed by him from my drawings. When not otherwise stated the figures are magnified from 10 to 30 diameters.

PLATE I.

PLATE I.

SEROLIS CORNUTA.

Fig. 1. Male, natural size.

Fig. 2. Female, natural size.

Fig. 3. Immature male, natural size.

Fig. 4. Terminal joints of one of the anterior antennæ to show the sensory hairs (*b*).

Fig. 5. Terminal joints of one of the posterior antennæ.

Fig. 6. Isolated joint towards the middle of the flagellum of posterior antenna.

Fig. 7. Distal half of left mandible, upper surface.

Fig. 8. Distal half of right mandible, upper surface.

Fig. 9. Maxilla of second pair of appendages.

Fig. 10. Same appendage of opposite side to show the occasional asymmetry of the maxillæ.

Fig. 11. Maxillipede.

Fig. 12. First abdominal appendage of right side.

Fig. 13. Second abdominal appendage of right side.

Fig. 14. Third abdominal appendage of right side.

Fig. 15. Several of the hairs fringing the endopodite and exopodite of abdominal appendages.

Fig. 16. A portion of one of the same; more highly magnified.

Mintern Bros. lith.

SEROLIS CORNUTA, Studer.

PLATE II.

PLATE II.

Figs. 1–4. SEROLIS LATIFRONS.

Fig. 1. *Serolis latifrons* (variety), female.

Figs. 2, 3. Terminal portions of mandibles, upper surface.

Fig. 4. Terminal joint of second antenna, with commencement of flagellum.

Figs. 5–13. SEROLIS SCHYTHEI.

Fig. 5. A single joint from the filament of anterior antenna; *b*, sensory hair.

Fig. 6. Three joints from filament of posterior antenna in male.

Fig. 7. Spines from the inner surface of penultimate joint of second thoracic appendage.

Fig. 8. Third thoracic appendage of male.

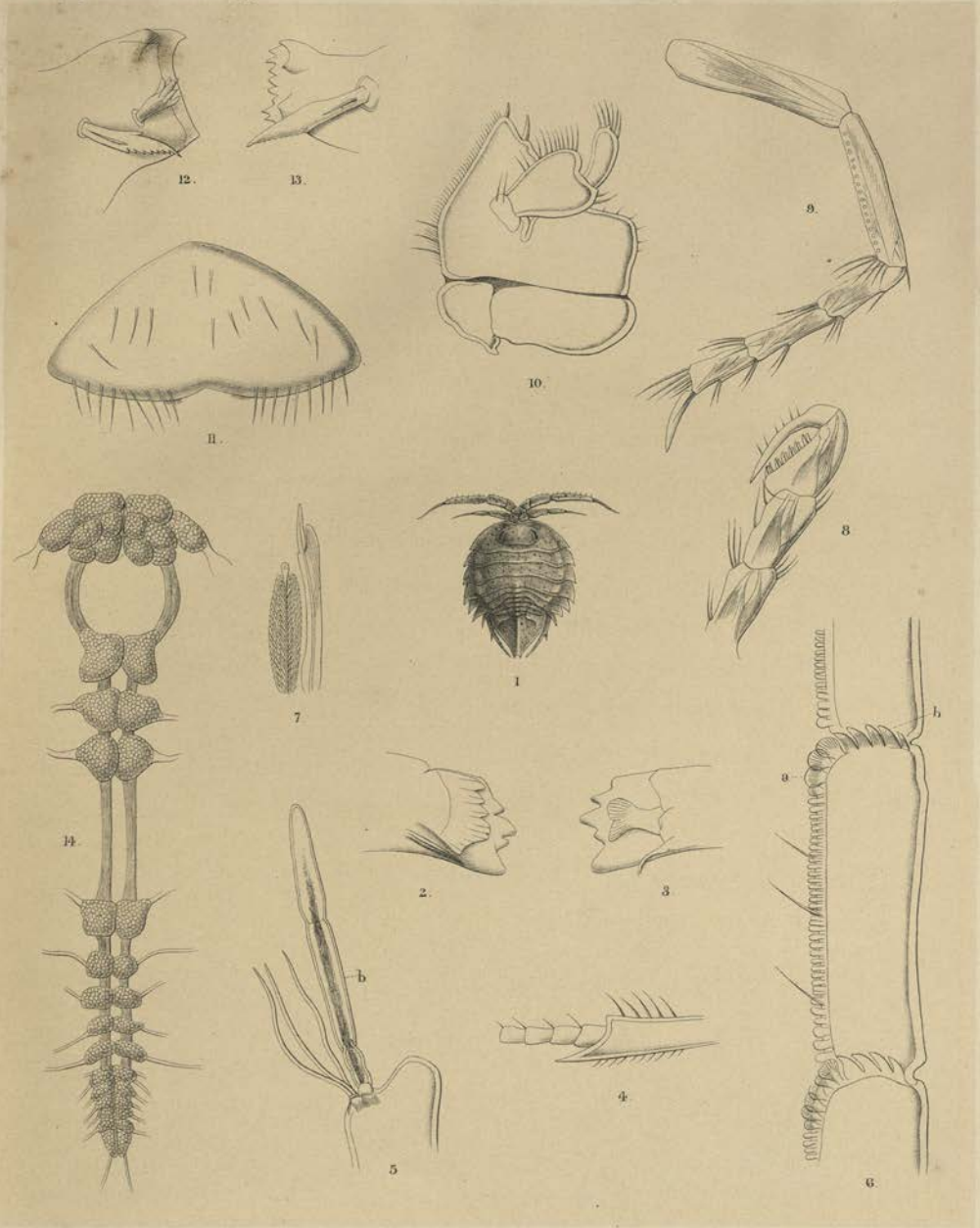
Fig. 9. One of the ambulatory limbs.

Fig. 10. Maxillipede.

Fig. 11. Upper lip.

Figs. 12, 13. Distal end of mandibles, upper surface.

Fig. 14. *Serolis septemcarinata*, nerve cords and ganglia.



Mintern. Bros. lith.

1–4. SEROLIS LATIFRONS, White. 5–13. SEROLIS SCHYTHEI, Lütken.
SEROLIS SEPTEMCARINATA, Miers.

PLATE III.

PLATE III.

Figs. 1–6. SEROLIS ANTARCTICA.

Fig. 1. Male, dorsal surface.

Fig. 2. Male, ventral surface.

Fig. 3. Female, dorsal surface.

Fig. 4. Sclerites and appendages in region of mouth, prepared by boiling in caustic potash.

Fig. 5. Third thoracic appendage of male.

Fig. 6. One of the ambulatory limbs.

Figs. 7–13. SEROLIS GRACILIS.

Fig. 7. Male, dorsal surface.

Fig. 8. Female, dorsal surface.

Fig. 9. Mandible, lower surface.

Fig. 10. Maxillipede, lower surface.

Fig. 11. One of last pair of thoracic appendages of male.

Fig. 12. One of the hairs which fringe inner surface of distal joints of same appendage; more highly magnified.

Fig. 13. One of the second pair of antennæ.

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1–6. SEROLIS ANTARCTICA, Beddard. 7–12. SEROLIS GRACILIS, Beddard.

PLATE IV.

PLATE IV.

SEROLIS BROMLEYANA.

Fig. 1. Male, dorsal surface.

Fig. 2. Male, ventral surface.

Fig. 3. Male (variety), with longer epimera.

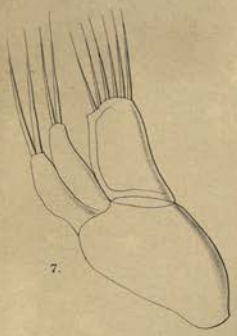
Fig. 4. Female, dorsal surface.

Fig. 5. Distal joints of third thoracic appendage of male.

Fig. 6. Distal joints of another individual fringed with numerous sensory hairs (*a*).

Fig. 7. Second maxilla.

Fig. 8. Maxillipede.



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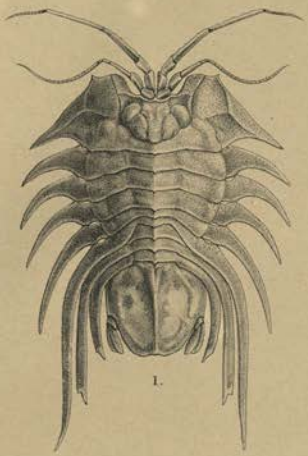

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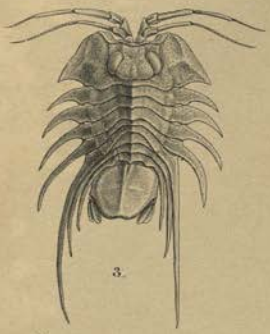

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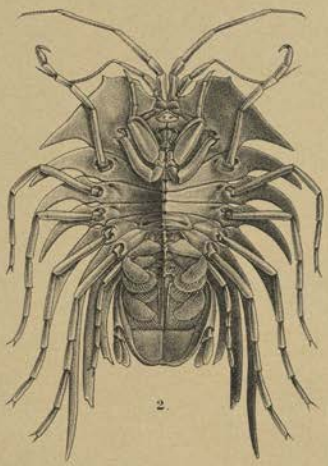

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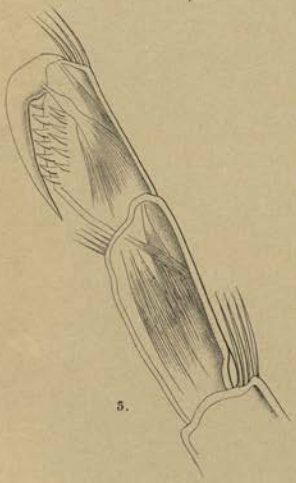

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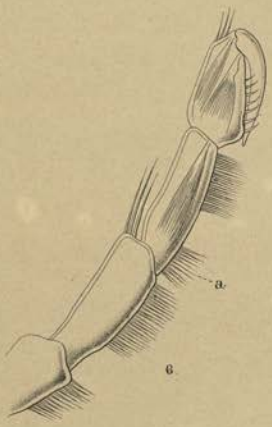


a.

6.

Mintern Bros. lith.

SEROLIS BROMLEYANA, Suhm.

PLATE V.

PLATE V.

Figs. 1–11. SEROLIS NEÆRA.

Fig. 1. Male, dorsal surface.

Fig. 2. Male, ventral surface.

Fig. 3. Female, dorsal surface.

Fig. 4. Female, ventral surface, displaying the eggs within the brood cavity.

Fig. 5. Tip of the filament of anterior antenna to show the presence of two kinds of sensory hairs (*a*, *b*).

Fig. 6. Maxillipede.

Fig. 7. Spines fringing inner surface of penultimate joint of second pair of thoracic appendages.

Fig. 8. One of the third pair of thoracic appendages of male.

Fig. 9. Hairs from penultimate joint of same appendage.

Fig. 10. A portion of one of the ambulatory limbs.

Fig. 11. One of fourth pair of abdominal appendages.

Figs. 12–14. SEROLIS PARADOXA.

Fig. 12. Distal half of one of the third thoracic appendages in female.

Fig. 13. Distal half of one of the third thoracic appendages in male.

Fig. 14. One of the first pair of maxillæ.

Mintern Bros. lith.

1—11. SEROLIS NEÆRA, Beddard. 12—14. SEROLIS PARADOXA, Fabricius.

PLATE VI.

PLATE VI.

Figs. 1–2. SEROLIS TUBERCULATA.

Fig. 1. Female; magnified three diameters.

Fig. 2. One of the second pair of antennæ.

Figs. 3–8. SEROLIS AUSTRALIENSIS.

Fig. 3. Male, ventral surface; magnified three diameters.

Fig. 4. Female, dorsal surface; magnified three diameters.

Fig. 5. Two joints from filament of first antenna; *b*, sensory hairs.

Fig. 6. Maxillipede of left side.

Fig. 7. Male, dorsal surface.

Fig. 8. One of the thoracic limbs.

Figs. 9–15. SEROLIS CONVEXA.

Fig. 9. Second thoracic appendage of male; *a*, tuft of sensory hairs.

Fig. 10. Third thoracic appendage of male.

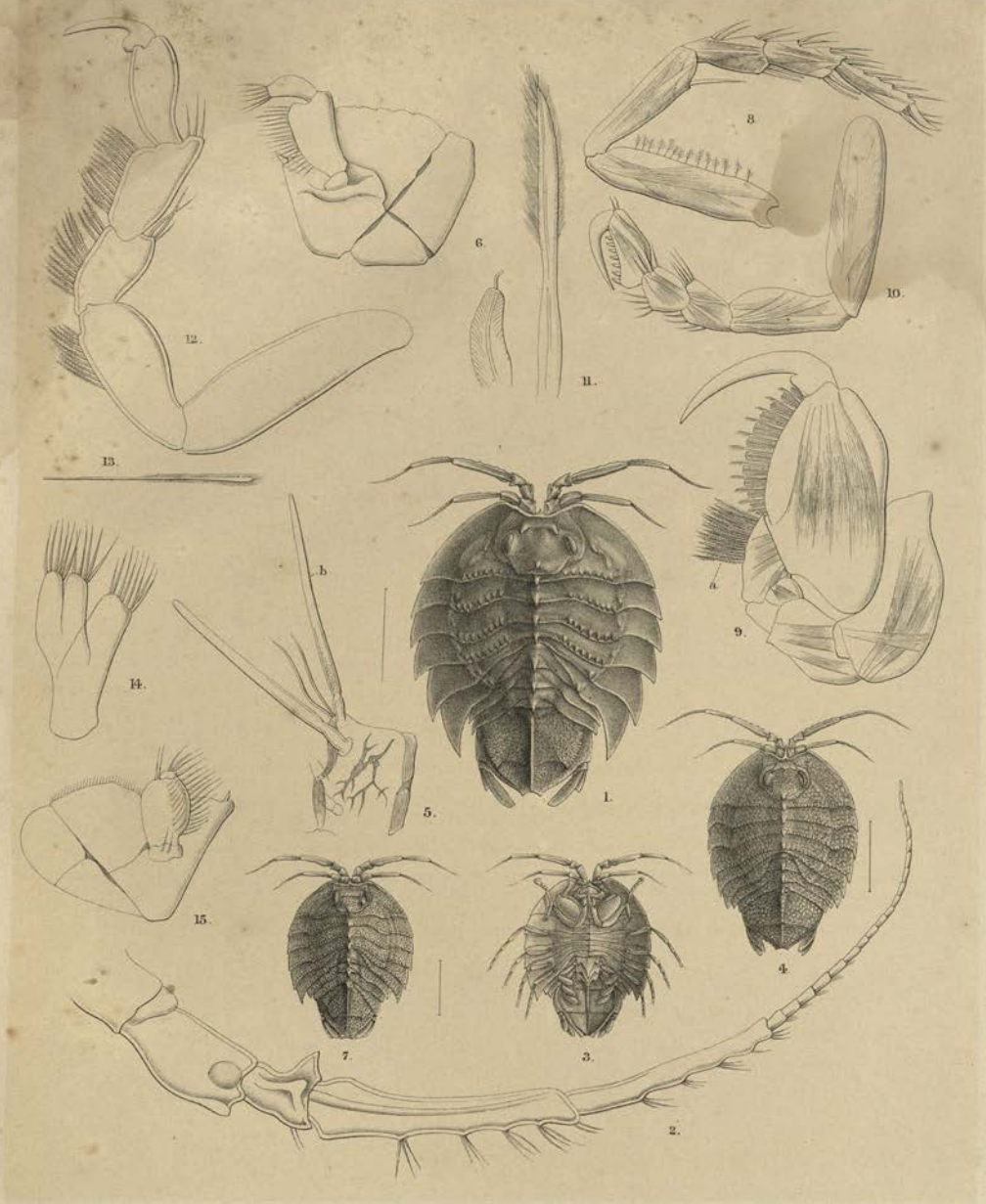
Fig. 11. Two hairs from inner side of penultimate joint of second thoracic appendage

Fig. 12. Terminal thoracic appendage of male.

Fig. 13. One of the hairs fringing the distal joints of the same appendage.

Fig. 14. One of the second pair of maxillæ.

Fig. 15. Maxillipede of right side.



Mintern Bros. lith.

1–2. SEROLIS TUBERCULATA, Grube. 3–8. SEROLIS AUSTRALIENSIS, Beddard.
9–15. SEROLIS CONVEXA, Cunningham.

PLATE VII.

PLATE VII.

Fig. 1. *Serolis pallida*, female; magnified two diameters.

Figs. 2–7. SEROLIS MINUTA.

Fig. 2. Male; magnified about nine diameters.

Fig. 2′. Abdominal sterna and appendages; *b*, penial filament.

Fig. 3. Third thoracic appendage of male, right side.

Fig. 4. Antenna of first pair.

Fig. 5. Antenna of second pair.

Fig. 6. One of the ambulatory limbs.

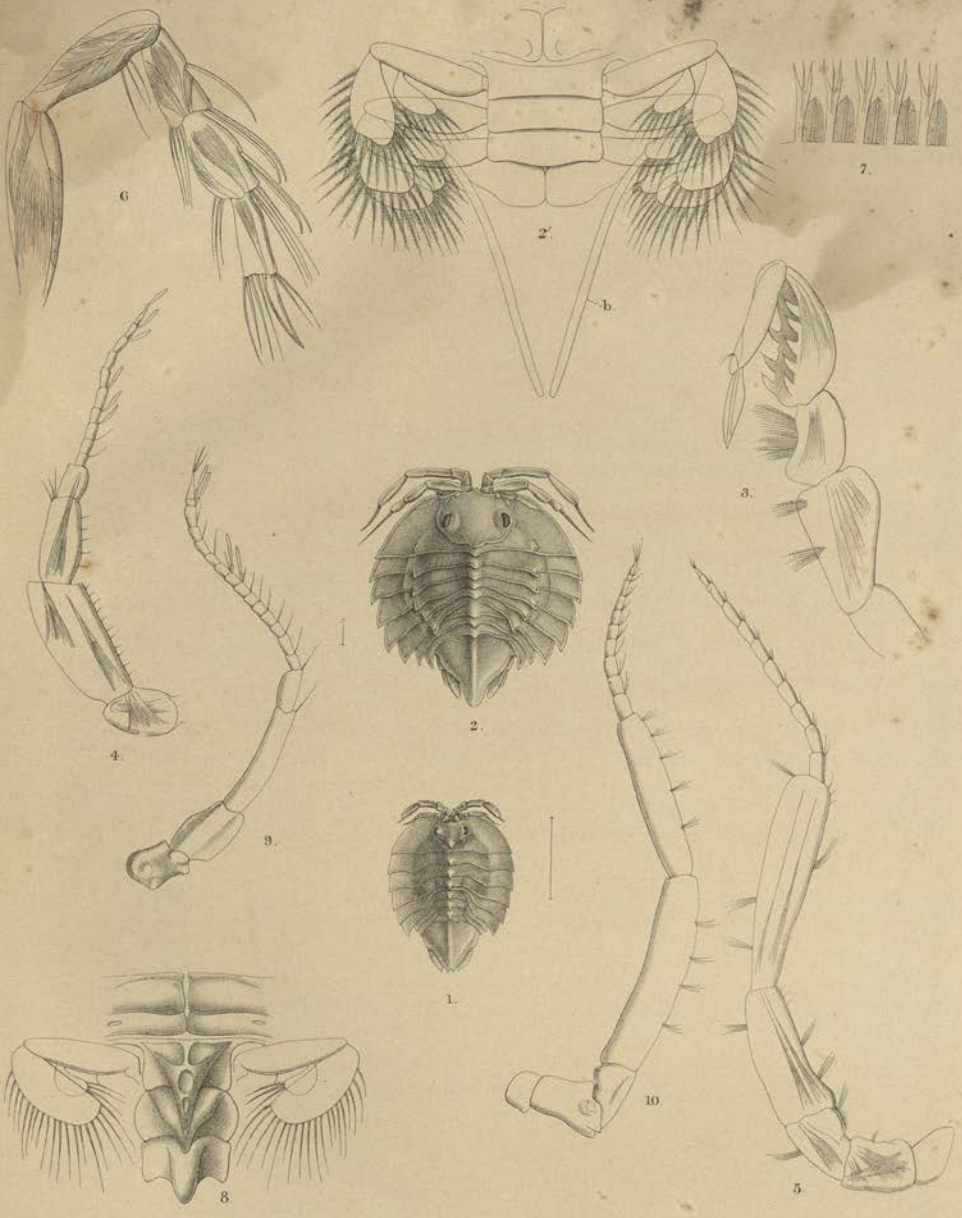
Fig. 7. Spines fringing the penultimate joint of the second thoracic appendage.

Figs. 8–10. SEROLIS LONGICAUDATA.

Fig. 8. Sterna of last thoracic and three first abdominal segments.

Fig. 9. Antenna of first pair.

Fig. 10. Antenna of second pair.



Mintern Bros. lith.

1. SEROLIS PALLIDA, Beddard. 2–7. SEROLIS MINUTA, Beddard.
8–10. SEROLIS LONGICAUDATA, Beddard.

PLATE VIII.

PLATE VIII.

Figs. 1, 2. SEROLIS LONGICAUDATA.

Fig. 1. Male, dorsal surface.

Fig. 2. Male, ventral surface; both figures enlarged about four diameters.

Figs. 3–5. SEROLIS SEPTEMCARINATA.

Fig. 3. Third thoracic appendage of male, left side.

Fig. 4. Base of penultimate joint of same appendage.

Fig. 5. One of the ambulatory limbs.

Figs. 6–16. SEROLIS PALLIDA.

Fig. 6. Antenna of second pair.

Fig. 7. Antenna of first pair.

Fig. 8. Two joints of the filament with sensory hairs; more highly magnified.

Fig. 9. Mandible of left side, lower surface.

Fig. 10. Terminal portion of left side; more highly magnified.

Fig. 11. First maxilla of right side.

Fig. 12. Maxillipede of left side, lower surface.

Fig. 13. One of the second pair of thoracic appendages.

Figs. 14, 15. Spines from inner surface of penultimate joint of same appendage; more highly magnified.

Fig. 16. Third thoracic appendage from right side of male.

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1–2 SEROLIS LONGICAUDATA, Beddard. 3–5. SEROLIS SEPTEMCARINATA, Miers.
6–16. SEROLIS PALLIDA, Beddard.

PLATE IX.

PLATE IX.

Structure of the Eye.

Fig. 1. Surface view of membrane limiting the "ommateum" below; *a*, perforations for the nerve fibres arranged in groups of four, corresponding to each retinula; *n*, nuclei.

Fig. 2. Semidiagrammatic section through the eye of *Serolis schythei*; *c*, corneal lenses; *n*, nuclei of Semper; *v*, vitreous body; *r*, retinula cells; *p*, pigmentiferous connective tissue corpuscles; *h*, hyaline cells; *s*, rhabdom.

Fig. 3. Single element of the eye of *Serolis cornuta*, depigmented and isolated by teasing; *r*, rhabdom; *r'*, its posterior filiform prolongation; *h*, hyaline cells; *n*, their nuclei.

Fig. 4. Single element of the eye of *Serolis cornuta* to show the pigment sheath surrounding the rhabdom (*r*).

Fig. 5. Single element of the eye of *Serolis schythei*; *r*, rhabdom; *h*, hyaline cell.

Fig. 6. One of the hyaline cells; *n*, its nucleus.

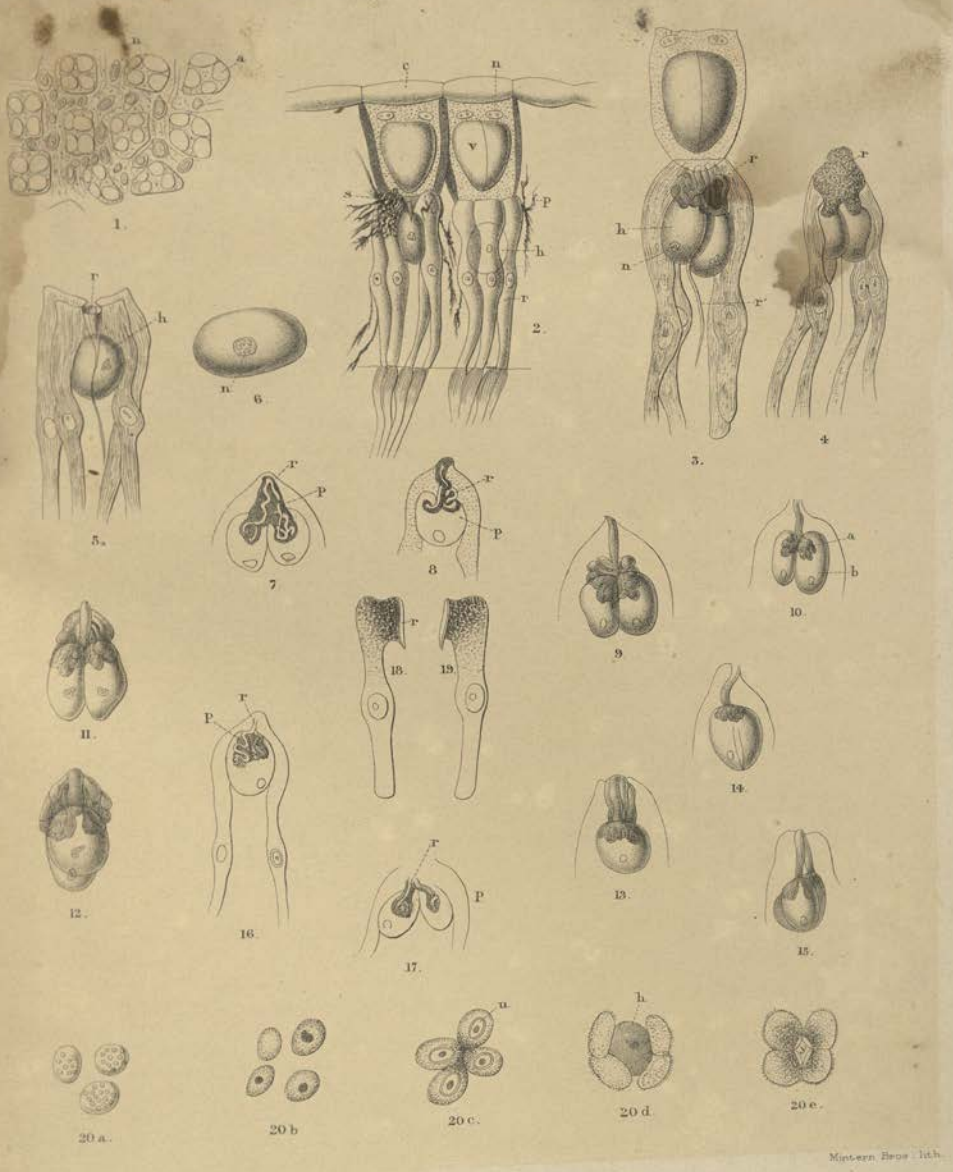
Figs. 7, 8. Transverse section through the upper part of the retinula of *Serolis schythei*; *r*, rhabdom; *p*, pigment.

Figs. 9–15. A series of figures to show the varying form of the rhabdom in *Serolis cornuta*.

Figs. 16, 17. Transverse section through the upper part of the retinula of *Serolis cornuta*; *r*, rhabdom; *p*, its pigment sheath.

Figs. 18, 19. Two isolated retinula cells of *Serolis schythei*; *r*, rhabdomere.

Fig. 20. Series of transverse sections through retinula of *Serolis schythei*; *a*, nervous rods below membrane; *b*, lower end of retinula cell just above the pigmented membrane; *c*, retinula cells at the level of the nucleus (*n*); *d*, four retinula cells surrounding the hyaline cell (*h*); *e*, upper extremity of the retinula cells; (*y*), rhabdomere.



STRUCTURE OF EYE.

PLATE X.

PLATE X.

Structure of the Eye, &c.

Fig. 1. Single element of the eye of *Serolis cornuta*, depigmented by nitric acid; *h*, hyaline cell which has absorbed the pigment.

Fig. 2. Dissection of *Serolis cornuta*; *h*, heart; *hep*, hepatic cæca; *od*, oviduct; *r*, rectum.

Fig. 3. Diagrammatic transverse section through the eye of *Serolis neœra*; *n*, nuclei of Semper; *l*, vitreous body; *(g)* mass of cells below the vitreous body traversed by a network of pigment.

Fig. 4. Masticatory stomach of *Serolis schythei*; *RP*, *LP*, ribbed lateral plates; *l*, *la*, *lp*, lateral ossicles; 1, 2, 3, pyloric ossicles.

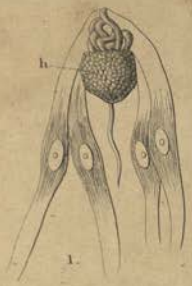
Fig. 5. Diagrammatic transverse section of eye of *Serolis bromleyana*; *h*, vitreous bodies; *c*, cornea; *m*, tissue in which vitreous bodies are imbedded.

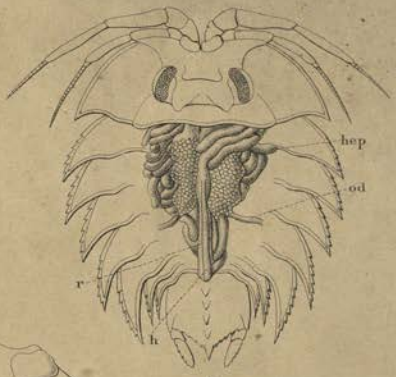
Fig. 6. Transverse section through the buccal region of *Serolis septemcarinata*; *a*, entrance to the buccal cavity; *m*, mandible; *b*, buccal cavity; *c*, integument bounding the lower surface of the body; *d*, salivary glands; *e*, connective tissue cells; *n*, nerve commissure.

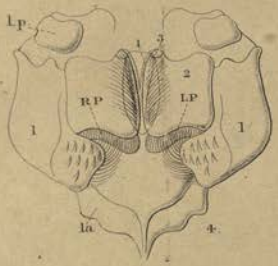
Fig. 7. Embryo of *Serolis antarctica*; *c*, telson.

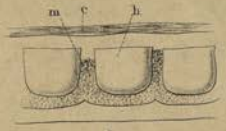
Fig. 8. Single element of the eye of *Serolis neœra* isolated by teasing in glycerin; *v*, vitreous body with pigment sheath; *g*, mass of cells below the vitreous body.

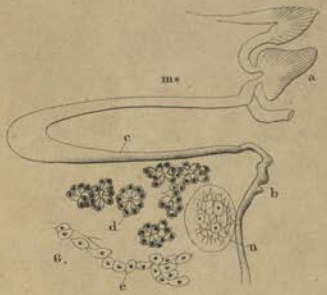
Fig. 9. Masticatory stomach of *Serolis bromleyana*; *m*, cardiac ossicle; *V*, ventral ossicle; *RP*, *LP*, ribbed lateral plates; *l*, *la*, *lp*, lateral ossicles; 1, 2, 3, pyloric ossicles; *s*, opening of pylorus; *t*, triangular ossicle.

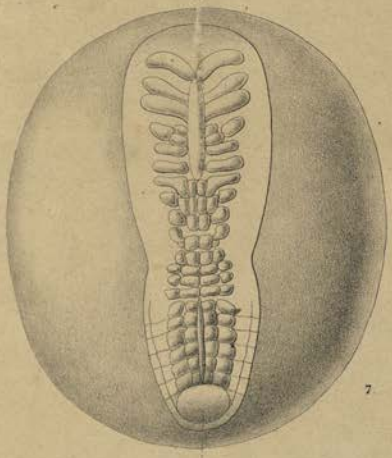


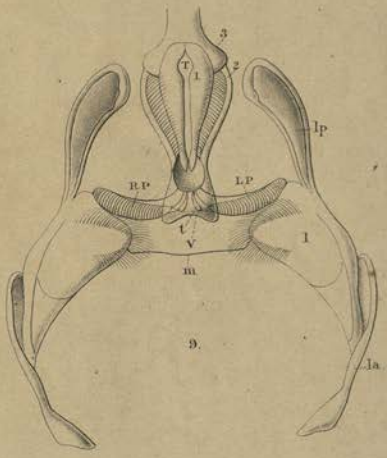












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ANATOMY OF SEROLIS.

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